

ELECTRIC CARS IN 2015: BUY TODAY, OR WAIT FOR VERSION 2.0?

AUSTRALIAN

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THE MARTIAN
THE HARD SCIENCE
BEHIND THE SCI-FI HIT

THE FUTURE OF FOOD

How to feed **9 BILLION** people

- Vertical farms
- **Food computers**
- Push-button dinners
- Drinkable meals
- + **MORE!**



OCTOBER 2015

SMART GUNS
Oxymoron or an
end to violence?

MARS: A HISTORY
Explaining our obsession
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TO CATCH A BOMBER
Identifying a terrorist by
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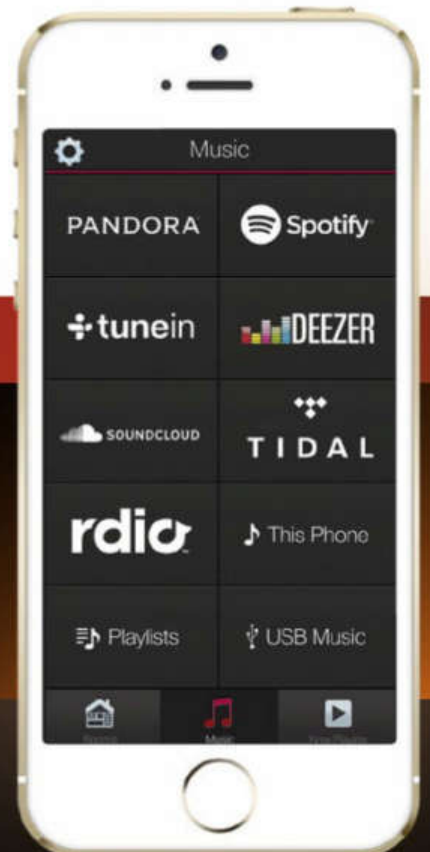


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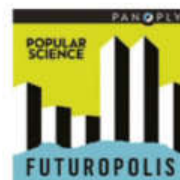
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A Bit About Us



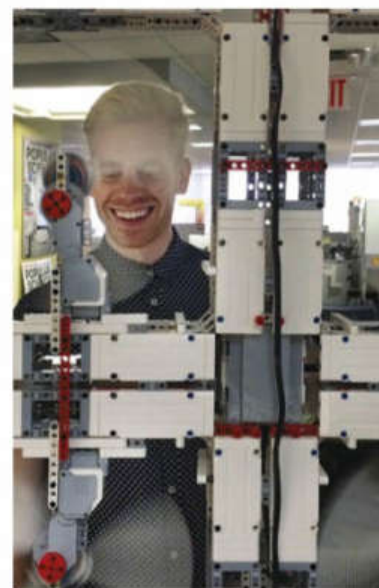
Zombie Science

Excited for season six of *The Walking Dead*? We are too. Actor Ross Marquand (you know him as Aaron) will talk all things zombie apocalypse this month on popsci.com.au.



HEAR THE FUTURE

In July, we launched a podcast called Futuropolis. This month we wrap up our first season. If you've ever wondered what finding love, communicating, or buying a sandwich will be like in the future, be sure to check it out on iTunes, SoundCloud, or your favorite podcast app.



KEEPING COOL

LEGO brought the Technic Wall of Fans to the *Popular Science* mothership this issue. The motion-activated fan wall is built with Mindstorms motors and sensors and Technic blocks. It's more work than AC, but more gratifying.

TIME WARP

Students at Friendswood High School in Friendswood, Texas sealed a time capsule in May. It included 11 issues of *Popular Science* (along with devices like an e-reader and a smartphone). The school's librarian Pat Torrefranca describes the choice of contents: "Twenty-five years from now, when the capsule is opened on our school's 100th anniversary, these items will elicit nostalgia, wonder, thought."



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THE FUTURE OF FOOD

How to feed a hungry planet in the digital age. No sunlight, soil, or pesticides required. (But there will be drones.)

Featuring

BRILLIANT 10

For the 14th year, *Popular Science* honours the brightest young minds in science and engineering. They're networking cars, decoding the brain, preventing plagues—and they're just getting started.

VERONIQUE GREENWOOD AND CASSANDRA WILLYARD

PAGE 46

LET'S TALK ABOUT MARTIANS

We found the perfect excuse to geek out on exploring Mars. And we invited the director of *The Martian* to join us.

ERIK SOFGE

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TO CATCH A BOMBMAKER

This is the story of a little-known FBI forensics lab and how it changed the global war on terror. **CLAY DILLOW**

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ON THE COVER

Tomorrow's corn will be increasingly high-tech. Illustration by Eric Heintz



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Unlocking the potential of a post-scarcity world

Good ol' Star Trek: The Next Generation fantasised a future where human societies had such easy access to resources and the systems to manage them that money became obsolete. "We work to better ourselves," said Captain Jean-Luc Picard to a lesser human once, rather griggishly I thought.

In Star Trek, way-out technologies like the replicator and warp drive made this post-scarcity society possible. When a vending machine can build you a steak or a T-shirt, traditional economies become basically meaningless.

And yet, some societies on Earth today live in many PRACTICAL ways a post-scarcity economy. Think about it: when was the last time you rocked up to an empty supermarket? Or a bakery with no bread? Or a petrol station with no petrol? In Australia today, if you have money you can get whatever you want, whenever you want it. It's gotten to the point where the truly rich need to seek truly ridiculous luxuries - diamond-studded iPhones, for example - to get that feeling of "I'm the only person with one of these" that conveyed so much social power in centuries past.

Yes, it's tough if you're poor or a citizen of one of the many remaining messed up regions on this planet. But

the challenge for the Haves in helping the Have Nots isn't a matter of there not being enough resources to go around. It's a matter of managing the resources more effectively.

Poor people today aren't poor because a harvest failed or a region dried up. They're poor because for some political reason, resources don't flow to where they live. There's more than enough spare food, spare transport capacity, spare manufacturing capacity and more to feed and clothe all seven billion humans.

What creates complication is that the producers of things - food, machinery, you name it - still expect to be paid for their work. The effrontery! Add in complex legal and political systems and you've got an over-complicated system that leads to that great killer of civilisations: inequality.

I'm not some pinko subversive insisting that everyone should live on \$50,000 a year no matter what they do, but I am suggesting that the

practice of throwing out food because it would hurt profits to donate what isn't sold will perhaps, hundreds of years in the future, be viewed with some degree of derision.

It's easy for me to sit in front of my word processor and opine that just because our agriculture currently produces enough kilojoules to feed everyone if only we could get the trucks running more efficiently, but I don't mean to understate the challenge. It is immense. But could it be done?

Certainly, the maths is equally compelling. We don't need another agricultural revolution, we need a supply-chain revolution. Giant multinational agricorps might not want to give away millions of dollars' worth of food they can't sell in Western markets, but they certainly wouldn't mind taking another 10% if they could get the stuff to, say, Africa on the cheap before it goes off.

Which brings us back to Star Trek and the one technology that could solve all our problems: the teleporter. Get on it scientists.

ANTHONY FORDHAM

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POPULAR SCIENCE

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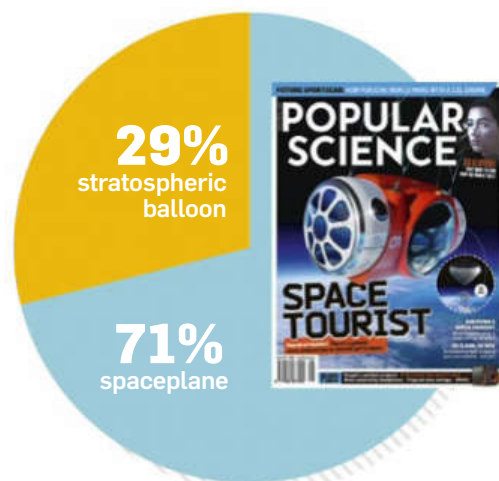
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For the Thrill

Last month, we asked readers which type of transportation they would take to the edge of space if offered a seat: spaceplane or stratospheric balloon? Looks like we've got some adrenaline junkies out there.



ADHIRAJ MATHUR I would choose the spaceplane because it's closer to the experience a real astronaut might have.

STEPHEN BEETS Spaceplane. It's WAY faster and more flexible in terms of mission capabilities than any balloon.

ELYSE DORM Balloon, but preferably if it's done like that first guy did it, floating up by yourself in a space suit, and then catapulting [sic] back to Earth when you're done. That would be fantastic!

JOB INSECURITY

My grandfather, retired U.S. Air Force Col. Dan Delton Fulgham, was an Air Force master balloonist in the 1950s. He would take balloons to the upper limits of the atmosphere and then parachute out, testing the rudimentary space suits of the era. Your article ["Wish You Were Here," August 2015] reminded me of his experiences.

Matt Fulgham, Richardson, Texas

BAR NONE

I really like the idea of cruising to an altitude of 30 km in a balloon ["Wish You Were Here," August 2015], however, I think the in-flight bartending service should be scrapped. The money saved could be used toward providing those aboard with light pressure suits and parachutes. A cabin decompression at 30,000 metres would be catastrophic!

Glenn Knox

TWEET OUT OF CONTEXT

Obviously aliens...
@GavanBoucher

WOOF
WOOF



MAN'S BEST FRIEND?

In the article "Robot Pets Have a Leg Up on Fido" [August 2015], we examined the idea of robotic companion animals. They wouldn't need to be fed, wouldn't soil the house, and could be left alone. But could humans bond with them? Our Facebook readers seemed more open to the notion than we expected.

RICK WAINIO Humans bond with anything that looks cute and acts like it could have self-awareness, so yes.

NAVIN KUMAR Humans can bond with machines, no biggie. Trick is for machines to bond with humans.

TONY CARLYLE Sure! I couldn't do without my smartphone.

CHRISTOS KYRIACOU The bond already exists between us and our computers, our iPads, our phones. The bond between us and any robot will be much easier to forge.



HAVE A COMMENT?

Write to us at
letters@popsci.com.au

SHOW & TELL

ONCE IN A BLUE MOON

At the end of July, we held an Instagram contest in which we asked followers to post their best photos of that month's blue moon; it occurred on the 31st. These three winners were chosen based upon clarity and composition.



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Now

EDITED BY **Michael Nuñez & Lindsey Kratochwill**

A Drone That Flies and Films for You

Shooting aerial footage from a drone is tricky. Pilots have to worry about throttle, pitch, yaw, and roll of the drone. When filming, they also need to consider camera focus and gimbal axis. The 3DR Solo Drone automates those chores, leaving you free to take killer shots of any scene.

With more than a dozen presets, the drone can fly in a circle, glide between two points, follow a person on the ground, and loop away from you for a selfie—all from its app and all with the push of a button. It is also the first drone to stream HD video from a GoPro camera, letting you monitor the live

26.75

Cost in dollars of the cheapest drone we could find online this month, a quadcopter the size of your hand.

feed from any smartphone or tablet.

A gaming-inspired controller, with a trigger at the top of the controller, lets you fly the Solo Drone up to 120 metres (the most allowed by US federal regulators). It's out-of-the-box flyable, so any novice can take professional-looking photos. But the Solo's biggest advantage—over close competitors like DJI's Phantom 3—might be its open-source

upgrades.

Dronemaker 3DR has opened its app to developers so they can create software hacks and accessories. For instance, a ballistic parachute might be deployed in an emergency (so your drone doesn't crash back to Earth). Now you just need to find a subject worthy of your Oscar ambitions.

REBECCA HARRINGTON



A gaming-style controller is intuitive, but pilots must supply their own tablet (a Nexus 7 is shown here). Software converts mawkish pawing into stable flight.



3DR SOLO DRONE

Price \$1,495

Weight 1.49 kg

Flight Time 25 minutes

Max Speed 88 km/h

Max Range of Live

Video 800 m.



Obsessed

Some things are just...better

LINDSEY KRATOCHWILL

(Prices are shown in US dollars... because we have to be cruel to be kind or something. Know your place, colonial peasant!)

1 ROBO-SAUCE

This children's picture book from Adam Rubin and Daniel Salmieri follows a young boy who tries a neon concoction called Robo-Sauce. It (predictably) turns him into a robot. Things go south when his parents and dog transform too. **\$19**

2 KNOCK KNOCK

This app, available for iOS and Android, uses Beacon technology to share whatever contact information or social-media handles you choose by knocking on your phone. It also builds chat rooms of nearby users. **Free**

3 BLUESMART LUGGAGE

Bluesmart is the Swiss Army knife of carry-on suitcases. Bluetooth location tracking ensures it won't go missing. A built-in scale keeps you from maxing out weight limits, and USB chargers keep your phone alive. **\$495**

4 TOPO COASTERS

Set your sweaty glass down on your favorite topographical regions with these cork coasters. The first set features Kentucky's Red River Gorge. Map coordinates are engraved on the reverse side in case you want to see the real thing. **\$39 for four**

5 M18 FUEL BRAKING GRINDER

Milwaukee has the first grinder tool that lets you make cuts and grind edges on battery power alone. Releasing the trigger stops the spinning wheel within

two seconds. Combined with a kickback reducer, it's a safety perk, and it gives the tool a longer life. **\$219**

6 DISNEY PLAYMATION

Playmation outfits kids with superhero gear to explore and carry out missions as their favorite character. It's made all the more realistic thanks to motion sensors and wireless tech. The first set released this month is based on *The Avengers*. **\$120**

7 E1 4K ACTION CAMERA

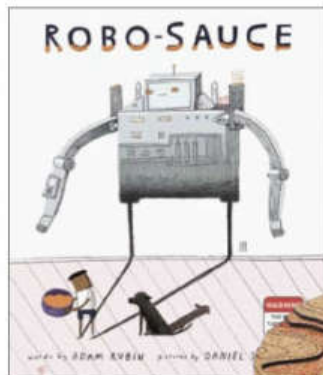
Digital imaging startup Z created a tiny camera to give documentarians and athletic auteurs more control than your average action camera. It has interchangeable lenses, can film in 4K at 24 frames per second, and has a 3D noise filter for, um, low-light scenes. **\$699**

8 ZOLT CHARGER PLUS

Laptops are great, but that brick you have to carry to plug it in and charge can be burdensome. Zolt packs power into an 85g tube. Plus it has two extra USB ports that can charge other devices at the same time. **\$100**

9 LECHAL

Stop navigating a new city staring at a smartphone. Lechal's shoes and insoles vibrate to guide wearers to their destination. Plus, each pair you purchase subsidizes a pair for someone who's visually challenged. **From \$80**



1



2



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10 STEVE JOBS

Danny Boyle's new film riffs on Walter Isaacson's biography of Apple's co-founder (played by Michael Fassbender). Go behind the scenes of Apple's product announcements, starting with the iMac. **October 9**



FROM TOP LEFT: COURTESY PENGUIN RANDOMHOUSE; COURTESY HUMIN; COURTESY BLUESMART; COURTESY MILWAUKEE; COURTESY DISNEY; COURTESY LECHAL; COURTESY UNIVERSAL PICTURES; COURTESY ZOLT; COURTESY TOM WILL MAKE

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Hollywood director Sam Mendes doesn't usually design high-performance sports cars. But he made an exception for James Bond. Mendes, who directed the latest 007 franchise film *Spectre*, worked with legendary auto designer Marek Reichman to create the movie's signature vehicle: the Aston Martin DB10. Their aesthetic goal: "It had to have the look of the character driving it," says Reichman, Aston Martin's chief creative officer. "It had to have a predatory nature."

ASTON MARTIN DB10

0-60 Speed
4.7 seconds
Engine
4.7 liter V8
Top Speed
305 km/h
Number Produced
10

And it had to be (almost) one of a kind. Though Aston Martin has been building Bond's cars over the course of 25 years, this is the only one that won't eventually hit the production line. As its name implies, the DB10 is a limited run of 10 state-of-the-art concepts. Reichman's engineers tailored each car to its scene. Some have roll cages. Some have flamethrowers in the exhaust. Plot spoiler: It's disguised in such a way that it will surprise audiences. "We had to make the design imperceptible," Reichman says.

Of course, even Bond's previous consumer-ready Aston Martins didn't come with flamethrowers. The genius of these concept cars is that they are harbingers of what's to come to the market. The DB10 shares a burly posture with Aston Martin's One-77, a previous concept car, but its longer wheelbase gives it a stout, grippier stance. Beneath its skin, it

incorporates the carmaker's three-year-old, 313 kW Vantage coupe, employing the same 4.7-liter V8 engine. And in a first for Aston Martin, the DB10 has acquired LEDs for headlights, giving it a thin, sharp, menacing stare. The LEDs also have a practical benefit. They shave weight off the front end and make it nimbler. "Any time you can take advantage of reducing mass, that has a performance advantage," says Reichman, who also designed the company's first \$2 million car—the limited-edition (24 in all) track-only, 12-cylinder, 596 kW Vulcan hypercar.

That car you can buy. The DB10 you can't. "There will be so many people asking: 'Can I have one? Can I have one?'" says Reichman, who won't divulge the car's production cost. "But there's only one person who can have this car and drive it. And that's 007."

JOSEPH OROVIC

"There will be many people asking if they can have one...but there's only one person who can drive this car."



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BMW i3

VS



TESLA MODEL S 85D

BMW i3

Price: \$65,000

PRO: Light and nippy in town, surprisingly spacious interior for four, can use council chargers for free.

CON: No fast charge system, less than 200km range even for hypermilers.

While there are a handful of pure electric cars on the market today, only two offer genuinely practical range. Even though they're very different rides, the fact that both can be used for the daily commute means comparison isn't entirely out of order. Let's dig in.

The i3 is a compact hatch, with 190km of "pamphlet" range and about 120km in typical traffic. The spacious 85D sedan boasts 490km on the sticker, but few drivers will muster the self-control over the car's astonishing torque to get much more than 350km.

Despite the Tesla's clear range

advantage, it does rely on specialised chargers - either a box installed at home or a very limited number of superchargers in Australia. The BMW can charge from a normal wall plug or from one of an increasing number of 6kW chargers dotted around major cities (an Android or iOS app helps you find the nearest).

Given the early state of EV infrastructure, both cars will primarily be used as city runabouts. And both are expensive - the i3 is a \$65,000 hatchback with less performance than most other hot hatches, while the Model S is a "luxury" sedan with the interior of a Honda Accord that costs \$151,507, cash.

The Model S has the greater potential. A car that - once the Superchargers link major cities and regional centres - can be used in every situation. The Supercharger system is impressive indeed. While 20 minutes for a full charge might seem too long, in reality a couple of hundred kilometres can be added in the time it takes to go to the toilet, have a coffee and check your smartphone.

The i3 is compelling in a different way. Light and easy to use in a crowded city, its off-the-line punch means performance is more than adequate for endless 0-60 accelerations around town. And the interior combines style and unusual materials to remind you that you're driving the future. So much curved unvarnished wood!

The Model S, on the other hand, wants to be just like any other car - except with amazing performance and a giant touchscreen full of controls and settings that will baffle anyone who can't wrangle an iPhone.

Yet its all-week range means you can drive it just like any other car. In the i3, depending on your commute, you may have to stick to Eco Pro+ mode to eke out an extra 30% of range (no AC, ugh!). And you'll need access to a charger at or near work if your round trip is much more than 100km.

Sure, these cars aren't in the same segment and the price difference is enormous. But here's the thing: despite its

TESLA MODEL S P85D

Price: \$151,507

PRO: Spacious 5-seater, range for long trips once Superchargers installed, incredible performance.

CON: Disappointing interior for price, no storage in front of cabin (without optional extras), only a handful of charging stations in Australia.

baffling lack of storage options in the front of the cabin, the Tesla will still be a good car in five, maybe even 10 years. The 2015 i3, on the other hand, is a bit of a marketing experiment. Its range and lack of a high-speed charge option mean it will only ever be an in-town runabout. It will be superseded by its own descendants, and soon.

Yet when it comes to design and laser-like focus of purpose, BMW's little space pod makes up a lot of ground. The interior is interesting and different. The Tesla is, well, okay I'm paying for the electric gubbins I guess.

Yes, you can get an i3 with an optional petrol generator for effectively infinite range and quick "recharge" but in the scope of this comparison, that's cheating.

What these cars show is that EVs have a future. Expensive, odd, not quite as good as their petrol equivalents in various ways, but definitely the shape of things to come. **ANTHONY FORDHAM**

*DTS: X available via update due late 2015. Please check au.yamaha.com for DTS: X and Dolby Atmos model compatibility.



AVENTAGE

Since its inception, AVENTAGE has epitomised market-leading innovation bringing studio-grade performance and state-of-the-art technology into the home.

The new AVENTAGE Series VI features object-based audio including DTS: X* and Dolby Atmos*, presenting the future of entertainment with incredible cinema sound.

Discover an exhilarating partnership in sound. Object-based audio and Yamaha.

au.yamaha.com



The Setup

Make It Out Alive

Three essential tools to conquer the wild (or weather the End Times)

MICHAEL NUÑEZ



1 KNIPER MULTITOOL

Throwing knives are usually made for one purpose: to be hurled end over end until they embed in a wood surface, or... something else. The Kniper is fun like that, but it also adds 22 important functions, including a fork, range finder, pry bar, sundial, wire stripper, wrench, saw, bottle opener, and screwdrivers. The Kniper is milled from high-carbon steel and is finely balanced, so it's easy to hit your target. Oh, yeah: It also has a tobacco pipe (in case you haven't kicked the habit yet). **\$205**

2 BREITLING EMERGENCY

Pilots, anglers, and hardcore bushwalkers often carry personal locator beacons to send distress signals if something should go wrong. Breitling's engineers have encased one in a watch. The Emergency can transmit to the international Cospas-Sarsat system, which has saved more than 37,000 lives worldwide since 1979. **\$23,532**

3 VSSL TORCH

At night, it's easy to take the wrong step. The VSSL torch's super-bright LEDs lead the way and can last more than 20 hours. It also holds lip-balm-size canisters for gear like a fire-starting kit, trail markers, a first-aid kit and, our favourite, an emergency tent. **\$145**

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GOOGLE [X]'S **ASTRO TELLER** SEES THE FUTURE

If only he'd tell us what it is.

EDITED AND CONDENSED BY MICHAEL NUÑEZ
PHOTOGRAPH BY CODY PICKENS

In August, Google made the surprise announcement that it was changing the company's name to Alphabet. Under the new structure, the moneymaking advertising business was separated from its loftier moonshot projects such as Google Glass, self-driving cars, and Internet delivery balloons. Astro Teller, who heads Google[x], the division that oversees those projects, spoke to *Popular Science* days before the news broke. He talked about the skepticism investors have over long-shot projects, why such projects are necessary to Google's survival, and how he culls the winners from the losers.

Popular Science: How do you vet moonshot ideas?

Astro Teller: We probably look at 1,000 ideas, for a few hours each, for every self-driving-car project we end up with. So it depends on where the project's Achilles' heels are. If it has only one Achilles' heel, it can take a long time to find it. If it has many, you can find one quickly.

PS: Give me an example.

AT: Yesterday I was in a room with 30 people discussing a potential new project, and they were pitching their hearts out. And frankly, they had me excited. The idea had to do with the ocean. And they were telling me why it was going to be important. Eventually I said: "Look, I'll give you three choices: Between sharks, storms, and pirates, which is the most likely to kill this project?" Everyone started laughing—not because I was kidding, but because

that question sounds funny and yet was totally appropriate. I didn't want to find out in a year from now this idea wasn't going to work because of pirates.

PS: What was the idea?

AT: I can't tell you. And I realise that's why we're often painted as a secretive organisation. But that's not our intention. I want to be able to kill projects as fast as possible with as little emotional baggage as possible. One of the rate-limiting issues of innovation is that

We've been tasked by Google with producing long-term results. Like all other parts of Google, we are held to the standard of producing value. But we still aspire to a strong return on investment. We don't take on Google Glass or the self-driving-car project or Project Loon unless we think that on a risk-adjusted basis, it's worth Google's money. But that's different from saying we have to produce liquid value by today or it's all worthless. That's not the spirit of long-term bets.

"Between sharks, storms, and pirates, which is the most likely to kill this project?"

people have a hard time killing their projects. So the more we are publicly committed to a project, the harder it becomes for us to kill it. If I tell you we're making a space elevator or an anti-gravity machine, and then next week we find a flaw in the idea, people would resist ending the project partly because the public has gotten excited about it. So it's not that we don't want to share it with the public. We just want to be sure of our thesis before taking victory laps.


PS: Skeptics and Google's own investors say these projects take too long and that they're too future-forward. How do you respond?

AT: I'm not even sure what that means, "too future-forward." That sounds like a compliment, not an insult. Our goal is not to produce immediate results.

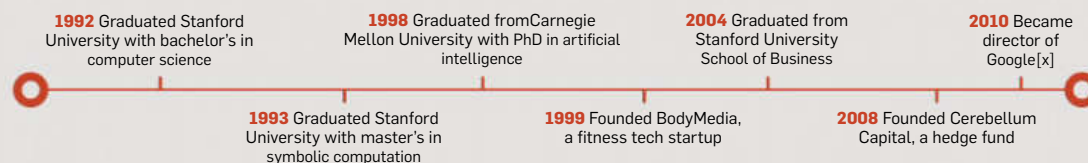
PS: What are you most proud of?

AT: It's not any one project. It's the factory. Our goal is to make a moonshot factory, to systematise innovation in an efficient and productive way—and to kill things when we have to. The truth is that most companies end up littered with a huge number of un-killed projects because there isn't the culture in place, the belief structure in place that allows those projects to get ended quickly. Two days ago, we killed the largest project we've worked on here. It's been going for more than two years and had 20-some people working on it.

PS: What was it?

AT: I can't tell you. It was an unannounced project. And it's good that we didn't announce it, for exactly the reason I said [laughs]. 

HOW ASTRO TELLER BECAME CAPTAIN OF MOONSHOTS



How It Works

Angling for a Perfect Blend

When choosing a blender, most people focus on speed. The logic goes: The faster blades spin, the better they pulverise fruits and vegetables, and the better the resulting smoothie, soup, pesto, or cocktail. Not so, say the engineers at Electrolux. Too much force crushes seeds, which busts them open and releases enzymes that make for a bitter taste. So, instead of designing a faster motor, the company tilted the canister. The angle creates an irregular funnel within the mixture, allowing the food to circulate evenly. And, they've employed titanium-coated blades of different shapes and purposes to thoroughly process it. The result is better texture and taste, with half the speed. **CORINNE IOZZIO**



ANGLED CANISTER

Engineers tilted the canister about 5 degrees from its vertical axis, which mimics the way a chef holds a mixing bowl to whip eggs or batter. The angle creates more turbulence in the funnel, circulating food around as well as up and down. This ensures that all ingredients receive equal attention from the blades below.

OFF-CENTRE MOTOR

The 1,200-watt motor is pitched about 5 degrees off-centre from the canister, which further agitates the flow of ingredients within the funnel.

LIFTING BLADES

S-shaped blades sweep the canister's sides and bottom, lifting pieces of food up and toward the other blades.

FINE-CUT BLADES

The shorter, thinner, upwardly angled blades slice open tough skins, like those on apricots.

CRUSHING BLADES

A pair of straight, blunt blades smashes hearty flesh, like that of carrots and potatoes. Since all the blades spin at about 10,000 RPM—roughly half the speed of popular high-speed blenders—they don't crack seeds.

TASTE TESTED: SPEED VERSUS DESIGN

Is the Electrolux's Masterpiece Collection blender better than a high-speed Vitamix blender? We ran a side-by-side taste test with a kale-and-fruit smoothie (the juice drinkers' poison of choice). Here's what we found:

ELECTROLUX MASTERPIECE COLLECTION JUG BLENDER

After a 45-second blend, the drink was perfectly smooth, and free of chunks that might clog a straw. Better yet, every sip tasted the same—the product of thorough mixing.

VITAMIX 7500

With a max RPM of 37,000, the blender successfully mashed all the juice's 11 ingredients. But it left a few macerated pieces of fruit behind, resulting in uneven texture and flavour. Confession: We re-processed this blend in the Electrolux post-test to enhance the drinkability.

ELECTROLUX MASTERPIECE COLLECTION JUG BLENDER
Speeds 3
Max capacity 2 litres
Max RPM 10,000 (approx.)
Price \$TBA

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80

Amount of water, in litres, saved per day using Nebia. The calculator on Nebia's website suggests Sydneysiders with electric heating will save almost \$250 per year.



NEBIA
Price: US\$400
URL: home.nebia.com

A water-wise shower that doesn't sacrifice luxury



Living in drought-prone and rain-scarce Australia, we're often told to use water more wisely, and when it comes to cutting down on water usage around the house the first suggestion is to reduce the length of our showers. But who can resist the allure of a long hot shower? What if we could reduce our water usage without reducing the length of our showers?

Nebia, a San Francisco based start-up, has managed to do just that with its sleek self-installable shower system that promises to offer a vastly superior shower experience, and reduce water consumption by up to 70%.

Rather than relying on traditional shower designs that use gravity to pass water through the shower head and into a projected stream of ersatz rain, the Nebia shower head instead employs an array of atomising nozzles. This technology is more typically used to inject fuel in rocket engines, as well as to more efficiently irrigate crops, but here it breaks up the water into millions of tiny droplets, producing a

fine mist that coats the entire body.

Of course small droplets of water lose heat faster, so to keep the mist warm, Nebia busted out the same computational fluid dynamics software commonly used to study jet engines.

If you think this sounds like the ultimate shower, you're not alone - Nebia has been backed by prominent figures including Apple's Tim Cook, Alphabet's (formerly Google) Eric Schmidt, and Y-Combinator as well as over \$US2.9 million in pledges on Kickstarter. That's a lot of showers.

The Nebia system isn't cheap, and unless you preordered it while the Kickstarter campaign was running you'll be waiting until at least May 2016 for a more sustainable shower. But if you can afford to make an investment in reduction of conspicuous consumption, you should start to see the Nebia paying for itself after a few years. **ROB NORTH**

How It Works:

1. Nebia fastens over your water supply with an adhesive strip
2. The atomising nozzles break the water stream into millions of tiny droplets
3. Water is dispersed, covering ten times the surface area of a standard shower



Clip a Pro Camera to Your iPhone

↓
Say you're at a concert and you want to shoot footage. Smartphone image sensors can't handle the low light or rapid action. The DxO One offers snap-on clarity. It attaches to your iPhone, and takes high-resolution photos and video.

The size of a stack of business cards, the DxO One clips onto an

iPhone's Lightning connector, so there's no need for fiddly Bluetooth pairing. You can select shutter speeds and play with depth-of-field aperture settings, something found only in high-end compact cameras and DSLRs. It also runs off its own battery, so it won't drain your iPhone's charge. You can store photos on the phone or to a MicroSD card, and share photos and video straight to your favorite

social-media channel.

DxO is known by professionals for its camera sensor rating system, and this is its first entry into the market it covers. It just so happens the company awarded itself a top rating, placing the DxO One among the best (and most expensive) cameras out there. For quick-draw shooters, it's a handy addition to the kit.

DAVE GERSHGORN



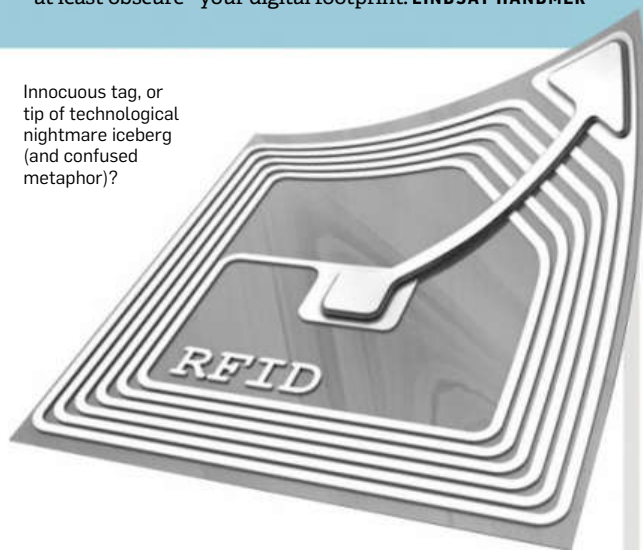
DXO ONE
Video Resolution
 1080p / 30 fps
Sensor Size
 1" (13.2x8.8mm)
Focal Length
 32mm (full-frame equivalent)
Aperture
 f/1.8 adjustable down to f/11
ISO Range
 100 to 51,200
Photo Resolution
 5,406-by-3,604 pixels
Price \$855

Obscure Your Digital Footprint

Without a concerted effort, it's almost impossible to avoid leaving your digital footprints all over the internet. And protecting that data from unsavoury sorts is only becoming harder - whether the "threat" is a nosy government, hackers out to publicly shame you, or merely overly persistent advertisers. Fortunately there are a range of advanced products and services available that can help do everything from physically protecting credit cards to obscuring an identity online. These are the latest ways to help erase - or at least obscure - your digital footprint. **LINDSAY HANDMER**



Innocuous tag, or tip of technological nightmare iceberg (and confused metaphor)?



PACSAFE RFID BLOCKING SLEEVE

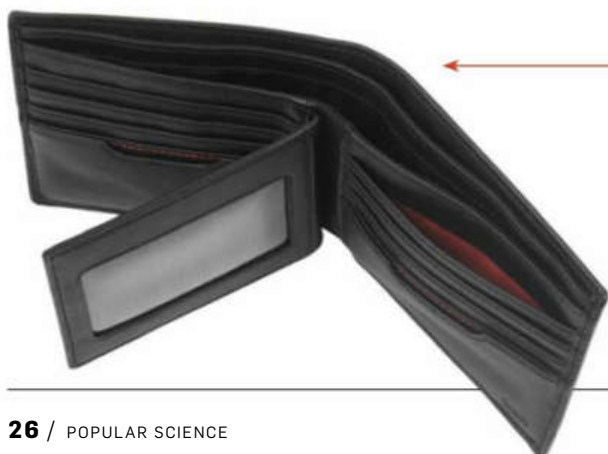
To protect individual RFID equipped cards, or other items such as a password, a blocking sleeve can be employed. Typically very cheap to buy, RFID shielding sleeves can also be made DIY from Aluminium foil and tape.

Price: \$8.45 for 25
www.travelgear.com.au



RFID SKIMMING

A type of digital theft, skimmers remotely read and steal information from RFID chips on many kinds of smart cards. Credit cards can be accessed while still in a wallet, and an identity can be copied from a passport just by walking nearby. Built-in card security can't always stop the practice, as an entire card can be cloned, encryption and all. The only way to protect against skimming is to physically block RFID access.



RFID BLOCKING WALLET

Designed to passively block RFID signals and protect all the cards in a wallet. RFID blockers act as a Faraday cage - a screen of conductive material that absorbs radio frequencies. While generally effective, some high powered RFID readers can overcome the protection.

Price: From \$60
www.samsoniteaustralia.com



ARMOURCARD

This Aussie invention actively jams attempts to read RFID chips. The credit card sized device slips into a wallet and can protect nearby cards. The unit has a built in battery and when activated by an RFID reader, jams the signal in a 10mm diameter to protect multiple cards.

Price: \$59.95
www.armourcard.com.au

2000

Max penalty, in dollars, of using workplace security footage for an "irrelevant purpose". So watch it.

DIGITAL SECURITY

A stolen smartphone or computer can yield a surprisingly large amount of data that the owner probably never even knew was being collected. Even erased or formatted HDDs or USB flash drives can have information recovered with the right software.



KINGSTON ENCRYPTED FLASH DRIVE

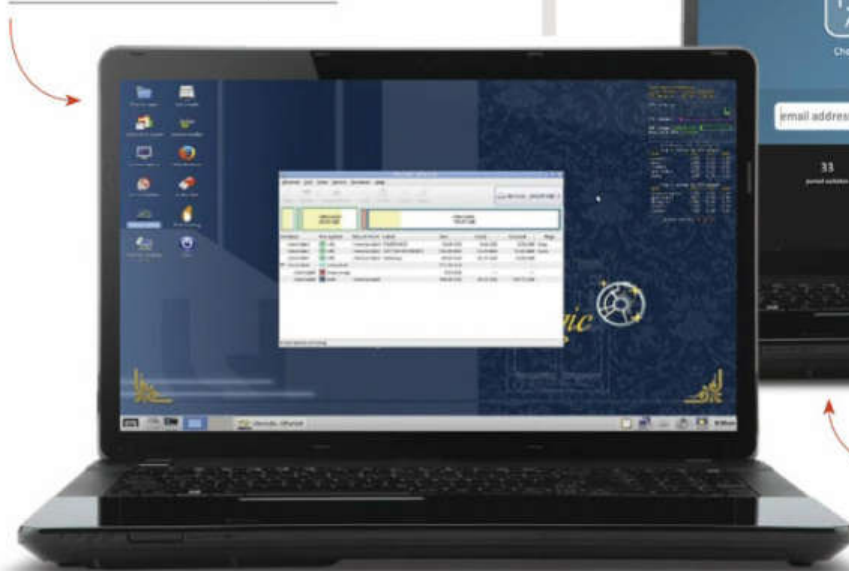
Always use a secure USB device to transport or store important data. The DataTraveler Vault Privacy 3.0 uses hardware based 256-bit encryption that is extremely well protected. It will also destroy stored data if access is attempted. Price: \$50 for 8GB www.kingston.com

ENCRYPTING HDDS

Included in Windows (Pro versions of Vista and later) is a utility called BitLocker that can encrypt the entire operating system on compatible computers. BitLocker uses AES 128-bit and 256-bit encryption for excellent security. Price: Free www.microsoft.com

PARTED MAGIC SECURE ERASE

Normally, data written to a HDD isn't actually removed when "deleted" and can be recovered. Even data written over can sometimes be extracted. For complete deletion, Secure Erase writes random data over and over so no information can be recovered. Price: \$15, www.partedmagic.com



DIGITAL SAFETY ONLINE

One of the easiest ways for data and information to be compromised is, well, by simply browsing the web. From Wi-Fi snooping to hacked accounts, it pays to take precautions. Start by turning on social media privacy settings and use a pseudonym and secondary email wherever possible. Using separate passwords for different accounts means if one is compromised the others are still safe.

BROWSER SECURITY

The simplest way to give some protection is to use a private browsing mode, such as Google Chrome Incognito. This stops the local system storing any information about online activities, but does not stop external websites and servers tracking digital movements. Ad networks are also one of the largest trackers of user's digital movements and data. Adblocker plugins are available for most web browsers and can help stop tracking and increase security.



INVIZBOX

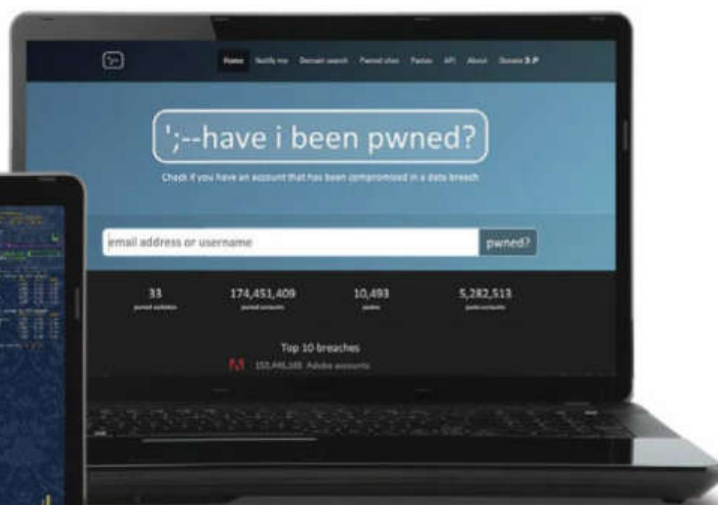
Taking the concept of Tor into real world hardware, InvizBox is a tiny portable security router. Simply plugging it between a computer and an internet connection will route all data through the Tor network. Aside from the extra security Tor provides, the advantage is the system is simply plug and play and requires no advanced user knowledge or setup. Price: \$75 www.invizbox.io

VIRTUAL PRIVATE NETWORK

Online, an IP address identifies each internet connection. Connecting to VPN routes internet traffic through a remote server, so its IP address is recorded and can't be traced back. VPN services can slow a fast connection. Price: From \$10 a month. www.torguard.net

TOR AND TAILS

Free software that enables anonymous communication through a worldwide volunteer network, Tor is used to provide a layer of security communication and hide online activities that users don't want exposed. Tails is a free operating system that can be run from a USB flash drive and is designed to give users enhanced security. Price: Free www.torproject.org



HAVE I BEEN PWNED

Websites are hacked all the time, with a range of personal and financial information released for anyone to access online. To check if a specific email address or user name has been exposed in an attack, simply search it on Have I Been Pwned. Price: Free www.haveibeenpwned.com

CNIDARIANS ROCK A FRESH 1990S STYLE



Corals in shallow water sometimes produce a fluorescent pigment that protects them from harmful UV rays, like a sunscreen. But when researchers from Israel and the UK found deepwater corals that produced a brilliant rainbow of hues, they were floored. "There might be something completely undiscovered in reefs that could be incredibly useful," says Jörg Wiedenmann, an oceanographer at the University of Southampton. The corals' pigments, he says, might help in the lab. For example, one can change from green to red when exposed to near-UV light—a capability that could help researchers track cancer growth or test the effects of potential drugs on cell cultures.

LEVI SHARPE





2.4

Estimated worth, in billions of
US dollars, of jobs, food, and
tourism that corals provide to
the US and its territories

Dick Rutan

On the Future of Flying



The Wright brothers aren't the only siblings to push the limits of flight: In 1986, pilot Dick Rutan flew nonstop around the world, spending nine days in the air on a single tank of fuel. He made the trip in a plane called *Voyager*, which his brother, Burt, designed. Today he's still at the forefront of aviation, busy building a new hyper-efficient engine and re-imagining what aircraft might be.

"I had an abnormal fascination for aviation at the expense of more normal character development."

7.3

Billions of airline passengers in 2034, as projected by the International Air Transport Association (compared with 3.3 billion in 2014)



“

Burt and I were issued flight plans instead of birth certificates. When we flew *Voyager* nonstop around the world, we showed that you could build a light, strong plane out of carbon fibre that will last indefinitely. Now we're at the dawn of learning how to fly into space—in planes. Burt designed *SpaceShipOne*, which won the Ansari X Prize. Its successor, Virgin Galactic's *SpaceShipTwo*, is on track to send civilians into space.

Innovators like Richard Branson of Virgin Galactic and Elon Musk of SpaceX can get you and me to space. And they can do it more efficiently and reliably than the government. Yes, there are risks involved. They will have problems and challenges, just as people did when the development of aeroplanes ramped up in the 1920s. But my mom always told me that it's not a crime to fail; it's a crime not to try.

With a company called Engineered Propulsion Systems, I'm now trying to transform planes' fuel flexibility and efficiency into something worthy of this century instead of the previous one. Our liquid-cooled cycle compression engines can run on any kind of fuel, from bacon grease to diesel to traditional jet fuel—a change that will revolutionise general aviation. The engines run beautifully smooth, with 35 per cent better efficiency, and they're incredibly quiet.

Disruptive noise is actually one thing that holds back commercial aviation. We have the ability to fly large planes faster than the speed of sound, but laws restrict their flight, in part, because of the sonic booms they create. We can solve that problem by taking hypersonic travel out of the air altogether. My vision is that we build something along the lines of the hyperloop: a system of carbon-fibre vacuum tubes. Inside, capsules can accelerate to, say, 10 times the speed of sound. Because they slide through an airless vacuum, there's no sound—and no sonic booms. You could go silently from Los Angeles to Tokyo in half an hour. It just takes some vision.

AS TOLD TO SARAH SCOLES

SMART PRINTERS PUTTING THE COPY-SHOP OUT OF BUSINESS



What's the most exciting bit of IT on the market right now? Did you say ordinary office printers aimed at small businesses? Okay... weird. But disruption happens in the most

unexpected of places, and the humble laser-printer-fax-scanner is one of those places.

Long the butt of "you stupid machine" jokes and occasional post-redundancy beatings in abandoned cornfields (see *Office Space*), a modern "multifunction device" is a far cry from the beige monstrosities of the 1990s.

Network enabled and packed with smarts, a printer like Fuji-Xerox's DocuCentre S2520 can scan, fax, print, collate documents, all that stuff that you used to have to send an intern down to Kinko's for.

This kind of functionality has

been around for 10 years or so, but until now was limited to expensive machines costing \$10,000 or more. Today, a business can get one for \$2,500 or lease it for mere dollars a day.

More significantly, today's printers now connect to a range of devices including compact scanners which allow businesses - imagine a doctor's receptionist or a warehouse - to quickly digitise paperwork instead of letting it pile up on a spike.

Despite the spread of tablets and smartphones, it seems we're still addicted to hard-copy.

ANTHONY FORDHAM



<0.01

Cost, in dollars, of printing a single black-and-white page on a current model laser printer.

The Search for Dark Matter



It makes up a quarter of the universe. Without it, galaxies would fall apart, and stars would spin off into space. Dark matter is five times more abundant than normal matter (the stuff that makes up trees and stars and us), yet scientists can't see it nor figure out what it is. The one thing they can say for sure: They're getting closer to an answer. **ILIMA LOOMIS**



600

Approximate number of collisions, in millions, inside the Large Hadron Collider every second

➔ **WIMPs**, or weakly interacting massive particles, got their name because they rarely run into normal matter. They've got to be big if they account for 27 per cent of the universe. And they are suspected to be particles, but even that remains to be seen.

1

Astronomers in the 1930s realised that if they added up all the visible matter in a galaxy cluster, the combined gravity would not be enough to hold everything together. There had to be something else there—and there had to be a lot of it. Scientists initially referred to it as the missing mass but have since dubbed it “dark matter.”

2

The Large Hadron Collider—the world's most powerful particle accelerator—is expected to identify dark matter once and for all. The facility stands the best chance of discovering **WIMPs**, the leading candidate for the stuff. “It could prove all these speculative, far-off, dreamy theories a reality,” says particle physicist Jonathan Feng.

3

Colliders aren't the only game in town. A host of experiments seeks to understand dark matter by studying its side effects. Some aim to observe dark matter bumping into normal particles here on Earth. Others look for the reaction of two dark-matter particles colliding in space or underground.

“You can memorise the periodic table, but that’s only 5 per cent of the universe.”

—**JONATHAN FENG**, PARTICLE PHYSICIST AT THE UNIVERSITY OF CALIFORNIA AT IRVINE

4

Scientists can also **detect dark matter by observing how its gravity bends light** that passes through it, like a cosmic prism. A team from the National Astronomical Observatory of Japan is surveying those warps and wobbles to create the first “dark-matter map,” which they aim to complete in 2019. It will reveal how dark matter is distributed—which gives clues to its mass and density.

5

Even if scientists identify dark matter, they'll be a long way from understanding how the universe works. The combined mass of dark and normal matter still leaves about 70 per cent of the universe unaccounted for. What makes up the rest? Say hello to dark energy, a force so weird and mysterious that scientists will be puzzling over it long after the dark-matter case is closed.

AN APPETITE FOR DESTRUCTION

We're entering a sixth extinction, and the world's most invasive species is to blame: humans



This summer the Internet seemed to wake up to the fact that we're in the midst of a mass extinction. These things happen periodically. The Permian extinction 252 million years ago wiped out 95 per cent of life on Earth, while the Cretaceous (65 million years ago) did in the dinosaurs. But this sixth one is different. Whereas powerful natural forces—volcanic eruptions, asteroid impacts, and atmospheric warming—were behind all five previous mass extinctions, this one is caused by us.

The indictment came in June, when a team led by Gerardo Ceballos of the Universidad Nacional Autónoma de México published a paper on extinction rates in the fossil record. They found that historically, two vertebrate species out of 10,000 went extinct every 100 years. When they added humans to the equation, the rate increased a hundredfold. In the past century, they calculated, nine species should have disappeared. Instead, 477 did.

The ostensible causes are all too familiar. We clear-cut forests, which leads to erosion and habitat loss. We overfish, causing marine ecosystems to collapse. We crank out billions of tonnes of greenhouse gases, which accelerates climate change. But there's an even more profound problem at work: Humans are hardwired for destruction.

Like all species, we have a strong instinct to survive, but unlike most, we serve that instinct through intellect. Our ability to problem-solve is unparalleled. In 200,000 years, we've spread to every continent, tripled our life spans, and adapted to extreme environments.

Our runaway success has come



“Ever since we migrated out of Africa, we have been transforming landscapes and causing extinctions.”

—MARK LOMOLINO, ECOLOGIST AT THE STATE UNIVERSITY OF NEW YORK

with profound and unexpected costs to the finite and interdependent system that is Earth. It's a frightening fact that “we, as one species, could have an impact rivalling that of a massive asteroid crashing into the Caribbean Sea,” says Mark Lomolino, an ecologist at the State University of New York.

A not-insignificant side effect of survival instinct is consuming today rather than saving for tomorrow. “We evolved to understand and act

8.7

Estimated number of species on Earth, in millions, according to a 2011 study; we've discovered only 25 per cent

on the short term,” says Paul Ehrlich, an ecologist at Stanford University involved in the June study. “Until very recently, we had no capability of acting in the long term.” Now, though, our technology allows us to model the future and plan ahead. “The principal causes of extinction are anthropogenic—therefore, things we can address and control,” Lomolino says. If human ingenuity has got us into this mess, then it can get us out.

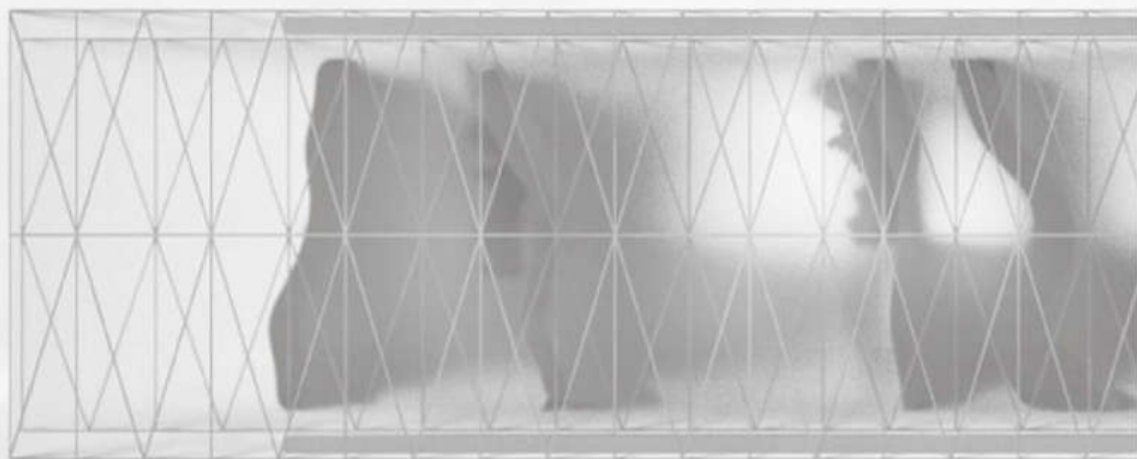
GRENNAN MILLIKEN

Concepts & Prototypes



City dwellers are reportedly 40 per cent more likely to develop mood disorders than people in rural areas. But walking for roughly 90 minutes in nature, according to a Stanford University study published in June, can calm the negative thoughts. The Essence Skyscraper is designed to provide urbanites with just such an experience. This 630-metre tower, envisioned by a Polish architectural team, won a 2015 skyscraper competition to redefine high-rises. Within the imagined 350,000 square metres, visitors cross 11 distinct ecosystems from around the world. "We wanted something that would blend into an urban fabric," says team member Jakub Pudo, "something that would allow us to go inside and get lost." **CORINNE IOZZIO**

TOUR THE NATURAL WORLD IN A SINGLE TOWER



**LEVEL 11
GLACIER**



**LEVEL 9
GRASSLAND**

NATURAL LAYERS

Visitors ascend through the ecosystems on a series of gradual ramps. The skyscraper's design lacks the vertical beams and horizontal concrete slabs typically found inside a building, so these gradients also provide an element of structural support.

SYNCHED CLIMATES

Ecosystems flow gently into one another, thus avoiding the climate-control nightmare of, say, going from African savanna straight onto an Antarctic glacier. Instead, similar climates, such as a jungle and a swamp, abut one another.

INNER WORKINGS

For visitors who want to quickly jump levels, staircases and elevators nest in a 11-metre gap between the building's facade and the interior ecosystems. Utilities, such as HVAC and power systems, hide beneath the glacier, desert, and river.

ISOLATED VIEWS

The all-glass building lets in sunlight, so there's no need for artificial lighting. But a synthetic coating gives the glass a foggy appearance, which obscures the urban jungle from the indoor one.

AMPLE HEADROOM

Ceilings range from 30 m in the desert to 80 m in the grassland to 90 m in the mountain range (to accommodate its towering peaks). Open space makes the landscapes feel more natural.

H₂O CYCLE

Water moves through the tower from top to bottom. It melts off a glacier and flows into a river, which drops down over a waterfall and percolates into a swamp before making its way into the ocean below.



LEVEL 0
UNDERWATER

ONE-STOP GLOBAL ADVENTURE

Ferdinand Magellan's journey around the world took three years. Circumnavigating the globe in the Essence Skyscraper requires only an afternoon.



Level Up

- 11 Glacier
- 10 Mountain
- 09 Grassland
- 08 River
- 07 Waterfall
- 06 Cave
- 05 Desert
- 04 Savanna
- 03 Swamp
- 02 Jungle
- 01 Ocean
- 00 Underwater



Time Machine

Guns Get Smarter

As any science-fiction fan knows, a smart gun is designed to work only for the person authorised to use it. Since the 19th century, Smith & Wesson, Colt, and even Silicon Valley have all attempted to disrupt the multibillion dollar gun industry and bring a theft-proof firearm to market. While politics and public opinion have hampered previous efforts, a new generation of smart guns is now on the cusp of becoming reality. **MATT GILES**

1886: S&W creates a gun that requires pulling the trigger and a lever simultaneously. Bonus: It's childproof. More than 500,000 are sold over its 50-plus-year run.

1974: Magna-Trigger launches. A magnet prevents the gun from firing unless a compatible magnetic ring is worn.

1977: Sci-fi comics embrace the idea. Judge Dredd's pistol, the Lawgiver, scans palm prints and self-destructs in anyone else's hand.

1994: Congress funds Sandia National Labs to study if smart guns can help lower the rate (11 per year) of police killed with their own weapon during a struggle.

1998: Colt unveils the Z40, a radio-frequency prototype with a matching wristband. Second-amendment groups of police killed with their own weapon during a struggle.

2001: Firearm-maker iGun produces a shotgun with an RFID-like magnetic tag. The market yawns, so the idea stalls.

2008: After working for nearly a decade on a multisensor biometric for a smart gun, the New Jersey Institute of Technology wins a \$250,000 grant to develop it.

2012: James Bond uses a smart gun that recognises his palm print in *Skyfall*. "Only you can fire it," Q tells him.

2014: German company Armatix releases the first smart gun commercially available in the United States: the iP1. This .22-caliber pistol pairs wirelessly with a watch. Gun shops initially agree to sell the iP1 but back out due to intense consumer pressure. Meanwhile, the

Smart Tech Challenges Foundation awards \$1 million to develop smart-gun technology. Teenager Kai Kloepper wins a portion of that for his fingerprint-activated pistol design, and starts company Aegen Technologies to commercialise it—all before he turns 18.

2015: Seattle holds the first-ever smart-gun symposium. Shortly after, a bill is introduced to Congress that would allocate grants to further smart gun research. "Once we have funding, it'll take just two years to get to market," says Donald Sebastian, senior VP of R&D at NJIT.

2018-ish: Four smart guns aim to enter the market, including NJIT's and Kloepper's. "People were hesitant about new technology," Kloepper says. "As our lives have become more integrated, everyone is racing to develop smart guns as quickly as possible."

"My gun has to be perfect or it could kill the smart-gun market forever."

—KAI KLOEPFER, FOUNDER OF AEGEN TECHNOLOGIES



FYI

DATING APPS GO VIRAL

Thanks to the growing popularity of apps like Tinder, one in five relationships now begins online. But users might find more than romance when they swipe right. In 2014, sexually transmitted disease rates in Rhode Island reached a 10-year



high. Cases of gonorrhea alone rose 30 per cent (in the state's relatively small population), mirroring a national US trend in STDs. Geospatial apps like Tinder and Grindr could be one reason: A 2014 study found that gay men who used them had higher rates of gonorrhea and chlamydia. But keep in mind, that's only a correlation. The usual suspects—drugs, alcohol, and multiple partners—are still at play, say state health officials. The apps likely enable risky behaviour, not cause it. Swipe safely, folks.

REBECCA HARRINGTON



Anthony Fordham is the editor of the Australian Edition of *Popular Science*. At 38, he was one of the last in the door of "old school" media and yearns for the days when words were only on paper.

Tomorrow's workers will live by their wits alone

COLUMN BY ANTHONY FORDHAM

As Australia's economy continues to contract despite the demonstrated superior economic management of the current mob in power (*cough*), the topic of what the next generation of workers is supposed to do for a crust continues to hot up.

Remember the old made-up-by-Westerners Chinese curse: "may you live in interesting times." Well, the interesting times are here. Like the dawn of the industrial revolution, and probably like the agricultural revolution before it, we're living through an era of sweeping change.

Immediately after WW2 the thing to do was get a job, stay in it for 40+ years slowly working your way up to some kind of equilibrium, and then retire with a gold or at least gold-plated or at least polished brass watch. Then, as Generation X came of age, the thing to do was bounce from job to job, staying for a decade here, five years there, maybe start a small business, maybe return to corporate life to boost the old superannuation. Today though... who knows.

Technology isn't the only thing making life tough for a new generation of workers, but it's a big part of it. In media, for instance, the increasing sophistication of desktop publishing software means we no longer need junior staff to shuffle files around, run copy or pore over printouts looking for typos (sic). And a cultural shift sees the humble Editorial Assistant replaced by a freelancer 20 years his or her senior, happy to churn articles and send them in via email.

Ah yes, email. We had it when I started back in 2000, but we didn't have free file-sharing services, effectively infinite internet allowances and so cheap-it's-virtually-free storage in the form of 16GB USB thumbdrives.

Our ability, in media, to work with people scattered across the country or indeed the world, has essentially killed the entry-level roles that used to give young writers much-needed experience. And this kind of thing is happening in all sorts of industries. If you've got a job already, you're okay. If you've never had a job, the likelihood of a company

TODAY THOUGH, ANYONE WITH THE FOCUS TO KEEP CHURNING ENGAGING VIDEOS WILL BUILD A BIG ENOUGH AUDIENCE TO MAKE SERIOUS POCKET MONEY.


giving you your "first shot" continues to diminish.

Yet some members of the millennial generation have become wealthier than anyone at their age ever has before. I speak of course of the YouTubers, the Kickstarters, the app-developers. The people who leave uni or even skip it to work on a project, an idea bubbling through their young minds.

I was like this once. I used to do comedy sketch stuff, back at uni. Was it good? Probably not, but maybe good enough to get sufficient views on YouTube to make me the \$25-30,000 a year equivalent of my first job. Yet in 1998, there was no mechanism to get my stuff out to a big enough audience.

Today though, anyone with the focus to keep churning engaging videos day after day will eventually build a big enough audience to make serious pocket money. It's an exciting prospect - good ideas and the ability to use your wits to entertain or inform can now, for the first time, keep a young person alive in an increasingly expensive world.

And that's just work vaguely equivalent to what I do here. What about all those graduates out there building things, inventing things, developing things and getting them noticed - and supported - on Kickstarter and similar crowdfunding platforms? There's no "cursus honorum" laid out for them by previous generations of office clones, but maybe that's a good thing.

Back in the 1990s, people in their 20s lived effectively isolated from the global economy. Today, the world is their oyster. A CV and a winning way in job interviews won't get you very far in 2015. But a keen mind and a love of hard work might just let you make your fortune 20 years earlier than us oldies. 



Number of staff members on Australian *Popular Science* under the age of 30.



The Future of Food

Traditional farming is outdated and broken. Thankfully, a raft of new technologies can efficiently feed the growing global population—if we adopt them quickly enough.

Farms Grow Up

BY KEVIN GRAY

This northern winter, as near-record snows piled up outside his 3,000-square-metre warehouse off Lake Michigan, Robert Colangelo stood inside, bathed in blue and red LEDs, and surrounded by crops of butter lettuce and herbs.

Located 60 kilometres outside Chicago, this is Green Sense Farms, the largest indoor vertical farm in the US. As the CEO of Green Sense, Colangelo grows produce—including micro-greens and basil—hydroponically, feeding them a constant stream of nutrient-rich water, in racks 8 m high, beneath specialised LEDs, monitored by computer, and harvested as often as twice a week. “We can grow a large volume, in a small footprint, 365 days a year,” says Colangelo. “We’re not subject to rain or drought. We control the environment. So the weather is perfect every single day.”

Indoor vertical farming has become a major player in the niche market of locally grown, high margin, perishable greens—such as kale, watercress, and lettuces. It eliminates the need for pesticides. It reduces the spoilage that occurs from trucking perishable produce 5,000 kilometres across a continent. It significantly cuts the carbon footprint of farm tractors and refrigerated trucks. And it meets the growing demand for fresh produce among middle-class urban dwellers.

Many say it could help avert a looming global food crisis and one day become the future of agriculture. The United Nations predicts that the global population will swell by 2.4 billion people by the middle of this century, and 66 per cent of the planet will live in cities. That presents a challenge to feeding everyone. With an increasing demand on the world’s arable land, and droughts and floods predicted to more frequently devastate crops—driving food prices higher—one solution is to grow food, in cities, where it’s needed.

Technologists and green-thinking entrepreneurs have already spent hundreds of millions of dollars raising indoor vertical crops across the globe. In eastern Japan, in a former Sony semiconductor factory, one plant scientist harvests 10,000 heads of lettuce a day. In New Jersey, a former



Green Sense Farms near Chicago blasts its plants with high-intensity LEDs for up to 22 hours at a time.

Cornell University agriculture professor, with backing from Goldman Sachs and others, is helping to turn a run-down steel factory into a 6,900-square-metre farm. It will be capable of turning out 900 tonnes of produce annually, eclipsing Colangelo’s farm when it opens this winter. The new farm will use 95 per cent less water than a field farm, and like others offer more productivity per hectare, and save energy costs such as tractor fuel.

At Green Sense, Colangelo partnered with electronics giant Philips, which created a unique spectrum of blue and red light—the optimal light for photosynthesis in leafy greens—in the 9,000 LEDs he uses. When plants sit directly beneath such specially tuned LEDs, they don’t spend energy growing upward. They grow outward in dense leaves, which optimises nutrient density and means less growing time. “We can turn a micro-green crop roughly every 12 days, baby greens about every 30 days, and lettuces about every 35 days,” Colangelo says. Field farmers get one or two chances a season to turn crops.

Colangelo sells his Green Sense branded produce to Whole Foods Market, which stocks it in 48 stores in eight states. “The stores get it fresh, and for the customer, it’s better quality,” Colangelo says.

He is also looking into new ways to improve his operation. He recently partnered with a genomic sequencing lab in Shenzhen, China, to identify seeds that best respond to LED lights. “You can create hybrid seeds, and then you can naturally crossbreed them with other plants so they double your crop yield,” he says. “They’ll be like non-GMO superseeds.”



Engineers can fine-tune LEDs to match each plant's needs, speeding up growth cycles.



The Wikipedia of Farming

How MIT's Media Lab is rewiring the way plants are grown

BY KEVIN GRAY

Two years ago, then MIT graduate student Caleb Harper built a fully networked farm of tomatoes, lettuce, and broccoli inside a fourth-floor lounge at the school's famed Media Lab. He hoped to prove he could use data science to optimise crop yields, boost nutrient density, and trim water consumption by 98 per cent compared with traditional dirt

farming, all of which he did. But there was no meaningful way to share his data with the world. Despite an ongoing boom in agricultural technology, no one cared about his findings or dared to share theirs. This September, he launched the Open Agriculture Initiative, the first open-source platform for global agriculture and food hackers.

Popular Science: How is agriculture not open-source? Don't we pretty much know how to grow a tomato?

Caleb Harper: No. Traditional agriculture is closed and opaque. It's understood by very few people at a production scale. How do I find nutritional-uptake studies on lettuce? Where can I get data on crop yields in Ghana? We want people to research this stuff, share it online, and grow healthier food and more of it around the world. There's a huge appetite for this.

PS: So who is hoarding all the useful information?

CH: Right now, there are 20,000-foot indoor farms popping up all over the world. But no one shares anything because they think their IP is so valuable. One place called PlantLab in the Netherlands has a warehouse full of little pods where they create microclimates, which in turn create a novel flavour, a novel shape, and specific nutrients in the plants. And then they patent their processes. To be fair to them, they're doing awesome work. This stuff can take a lifetime to figure out. But they are creating all this knowledge and then scooping it under a black box. We want to create plant-growing recipes that look like Wikipedia.

PS: How do you propose to do that?

CH: One thing we're developing is a shipping-container farm modified with networked sensors and growing environments. It can be used by other research institutions and by corporate cafeterias. So we'll all be connected to each other's data. Another cool thing is the Personal Food Computer. We released it for testing in September. It's a 600-by-600-mm cube with micro-sensors, an LED light bar, and an irrigation system. We can change the temperature, the CO₂ level, the amount of nutrients in the water, the water temperature, mineral fertiliser—all this stuff.

PS: It sounds like the state of 3D printing 10 years ago, when the open-source RepRap helped create a huge community of printer hackers.

CH: Exactly. Our Personal Food Computer is an open-source bio bot, a food bot for maker enthusiasts to create a community. What's been holding agtech back is that none of the black boxes and systems can talk to each other.

PS: So what can you do with it?

CH: People always want me to answer that. I dunno. It's like personal computers in the '70s. The extensions are endless. You can be an idiot and have fun, or revolutionise how tomatoes are grown. It could become a personal pharmacy. We can all be sequenced, and grow the food best for us. That's one of a thousand stories waiting to be written.



The Personal Food Computer is the first open-source food bot.

Food Minus Food

BY RACHEL FOBAR

Our attachment to food is antiquated. So the argument goes: It takes time and energy to buy and prepare, and it can lack nutrition (we tend to cook away the good stuff). We can now drink our meals. Meal-replacement shakes—different from protein drinks that serve as supplements—optimise nutrient efficiency, save money, and turn the messy business of eating with others into a hobby.

SOYLENT

Ever since Soylent launched as a powder in 2013, it's been a trend among Silicon Valley coders. Now it comes in even more convenient 400-ml drink bottles. Each bottle holds 1675 kilojoules (you need six or seven to maintain a minimum daily energy requirement for an active adult). The new release includes soy for its primary protein source and algae—in the form of algal oil—for half of its fat content. Texture: cow's milk.

AMBRONITE

Thought of as an organic alternative to Soylent, Ambronite is made from a list of easy-to-recognise, easy-to-pronounce ingredients, including oats, rice bran, and flaxseed. You can probably live off it, but it is pitched as a "productivity tool" for creative types stuck in lunch meetings or grinding through weekend hackathons. Each bag of powder contains a 2000-kilojoule serving with 30 grams of protein, 13 different vitamins, and fibre. Your poops need fibre.

DIY.SOYLENT

Soylent is not patented, so thousands of diet hackers have decided to make their own versions, posting them on diy.soylent.com. Rather than a one-drink-fits-all approach, the site offers customised meal-replacement recipes based on age, sex, weight, and daily activity level, and whether you want to reduce or maintain weight. For example, "Bachelor Chow" delivers 8,400 kilojoules per day and is made with only 10 ingredients.

The iPhone-Driven Farm

Cheap, networked technology is transforming our crops.

TAYLOR DOBBS

Since Dorn Cox began automating his 250-acre New Hampshire farm four years ago, he has installed dozens of sensors. Some measure moisture in soil around his squash. Some track temperatures in the greenhouse air around his cucumbers. Others track wind speed and rainfall in segments of field roughly a quarter-acre in size. When something is amiss—temperatures are too high or the soil is too dry—he receives an alert on his smartphone. He also sends out drones to survey his field crops for dryness, soil erosion, and plant health.

"On a farm, there's a lot going on," Cox says. "Being able to keep track of it all without having to hire more people is important. It lets you do a better, more efficient job."

For centuries, farming was an intuitive process. Today, it's networked, analytical, and data-driven. Large farms (1,000 acres or more) started the trend, adopting the tools of precision agriculture—using GPS-guided tractors, drones, and computer modelling to customise how each square centimetre of land is farmed. Farm managers can measure and map things like soil acidity and nitrogen levels, and then apply fertiliser to specific plants—not just spray and pray. As a result, they get the most out of every seed they plant. Such methods have reduced farm costs by an average of 15 per cent and increased yields by 13 per cent, according to a 2014 survey by the American Farm Bureau Federation.

Small farms—which make up 88 per cent of all farms in the US, according the Department of Agriculture—are now adopting similar methods, powered by a proliferation of affordable sensors, drones, cameras, wireless networks,

and data plans. And they sometimes see better results than large farms. Cox, for one, says he has cut labour and fertiliser costs by as much as 70 per cent, and in some cases doubled his crop yields. He and his fellow farmers also share data through farmhack.org. In the past, innovation came from individual experiments. Now, "if you're able to capture new data with the help of other farms," Cox says, "all those experiments add up to much faster learning."

At Cox's Tuckaway Farm, about 35 km northeast of Portsmouth, Cox uses farmOS, an open-source farm-management software he helped develop. He can also create 3-D models of crops to show biomass volume. He can

look at larger landscape patterns via drone. And he can share information in real time. His next innovation will be employing robots in the field. When corn grows to a mature height, it's difficult to get through the rows to apply nitrogen. Instead, farmers apply it to the soil at the start of a season and hope it lasts. But Rowbot—created by Minnesota agricultural engineer Kent Cavender-Bares and his two brothers, one a roboticist—is small and sturdy

Farming was once intuitive. Today, it's analytical and data-driven.

enough to carry several litres of nitrogen and work its way down the space between rows, applying nitrogen when needed.

"In the future, the machines will be out there doing work and at the same time learning about that field," says Cavender-Bares. That data will, in turn, affect how farmers like Cox manage their land. "We have the pieces to put this together," Cox says. "We haven't had that before. That's a big deal."

Designer Produce

BY BROOKE BOREL

Each year, groceries, restaurants, and hotel chains collectively toss out some 180 million kilograms of fresh potatoes due to bruising and black spots. (Consumers loathe a bruised spud.) Boise, Idaho, food giant Simplot—one of the largest privately held food producers in the nation—has now genetically modified potatoes so we'll waste less. Its new Innate line of Russet Burbank (a standard for French fries), Atlantic (a chip staple), and Ranger Russet (an all-purpose potato) is bred to have less bruising. Compared with typical potatoes, Innates also have up to 70 per cent less acrylamide—a potentially cancer-causing chemical formed when potatoes are cooked above 120 degrees, such as when frying French fries or baking chips. In other words, they're healthier. The new potatoes are among the latest GMOs with direct consumer benefits, joining the nonbrowning Arctic apple, and Pioneer's Plenish soybean oil, which contains the healthy fat omega-9.

Simplot—an 86-year-old company that invented the frozen French fry and dehydrated potato—spent more than 14 years devising the Innate varieties. To create them, engineers extracted genes from cultivated and wild potatoes, and inserted them into the DNA of its target varieties. In a process that scientists call "gene silencing," the new genes switch off the host genes that lead to bruising and acrylamide production.

This summer, Simplot's new potato line began landing in produce aisles, on restaurant plates, and on room-service trays in hotels. (In 2012, consumers ate 23 kg of potatoes per person.) But some big potato buyers, like McDonald's, aren't buying, likely because they fear consumers' reaction. Although 88 per cent of scientists say GMOs are safe to eat, only 37 per cent of the public agrees, according to a 2015 Pew Research Centre survey.

Still, it's unlikely consumers will notice or appreciate the new spuds. "I'm not convinced that the fact that it's low acrylamide will be looked upon by consumers as a big benefit," says Greg Jaffe, the biotechnology director at the Center for Science in the Public Interest, "because I don't think most consumers are aware of acrylamide and the issues around it."



In 2015, food giant Simplot released genetically modified potatoes, designed to reduce bruising, the latest GMO on the market.



RDM Aquaculture in Indiana grows these Pacific white shrimp in closed-system pools, without the need for costly antibiotics.



The US Midwest Is A New Ocean

The most sustainable way to raise seafood might be on land.

BY LOIS PARSHLEY

Americans eat about 2 billion kilograms of seafood a year, but many of them don't know where the fish or shellfish come from—or even what they're eating. (Seafood can be intentionally mislabeled.) Karla-nea Brown's family-run shrimp farm, in landlocked Indiana, offers a cheaper, sustainable, and more transparent approach.

For years, the Brown family had raised hogs but became frustrated by plummeting prices in the market. So they began looking into aquaculture. In 2010, they decided to raise shrimp. Their farm, RDM Aquaculture, is now the largest such operation in Indiana—which is a US leader in inland shrimp farming—and produces 250,000 shrimp a month.

Today, much of the world's shrimp is grown in small farms in Southeast Asia that don't always measure up to US health-safety regulations. In 2011, the Government Accountability Office cited several examples of imported samples tainted with unregulated antibiotics. Farms like Brown's provide a safe and healthier alternative.

Brown raises her Pacific white shrimp indoors in large recirculating plastic tanks that rely on bacteria to consume waste. The closed-loop system is surprisingly low-tech: The tanks are essentially swimming pools with air pumped in to keep the bacteria in suspension—a system based on Texas A&M research, and refined by Brown and her family. The tanks don't require filters to keep the water clean, and that clean water removes the need


for costly antibiotics. Brown's farm is now one of 11 in the state, up from three when she started in 2010. "Indiana could become the shrimp capital of the world," Brown says.

That might not be as far-fetched as it sounds. In a 2011 report, the United Nations' Food and Agriculture Organization found that around 90 per cent of the world's fisheries are fully exploited or overexploited. To take pressure off ocean stocks, the world must produce an additional 40 million tonnes of farmed seafood over the next 15 years, according to Michael

Rubino, director of the National Oceanic and Atmospheric Administration fisheries aquaculture program. Aquaculture is already the fastest-growing food-producing sector in the United States. There is one drawback to Brown's approach: Even recirculating systems often feed their stock other seafood that has

"The ocean is dying every day unless we change things. By moving inland, we have a chance to keep seafood going."

been harvested from the ocean by dredging or by other potentially damaging methods. Scientists have developed an alternative, vegetarian-based feed for carnivorous fish, and this might eventually help.

As for Brown, she is already looking to branch out to raising yabbies, oysters, and talapia. "We have to keep growing," Brown says. "The ocean is dying every day unless we change things. By moving inland, we have a chance to keep seafood going." 

Push-Button Dinner

DAVE GERSHGORN

The ability to create food with the press of a lever has been a science-fiction staple for decades. While 3D food printers have not reached *Star Trek* levels, they can make simple foods, and will soon be pressing and cooking your burgers. Here are a few new products—and a taste of what's to come.



Foodini, Natural Machines

Prints pasta, crackers, and burgers. However, the ingredients—such as ground beef—must be prepped and fed into the machine to be printed and then cooked separately. The next model is expected to cook as well.



ChefJet Pro, 3D Systems

Engineered to print intricate confections, like multicoloured candies and wedding toppers. The ChefJet Pro uses powdered printing sugar in flavours such as chocolate, vanilla, mint, and watermelon.



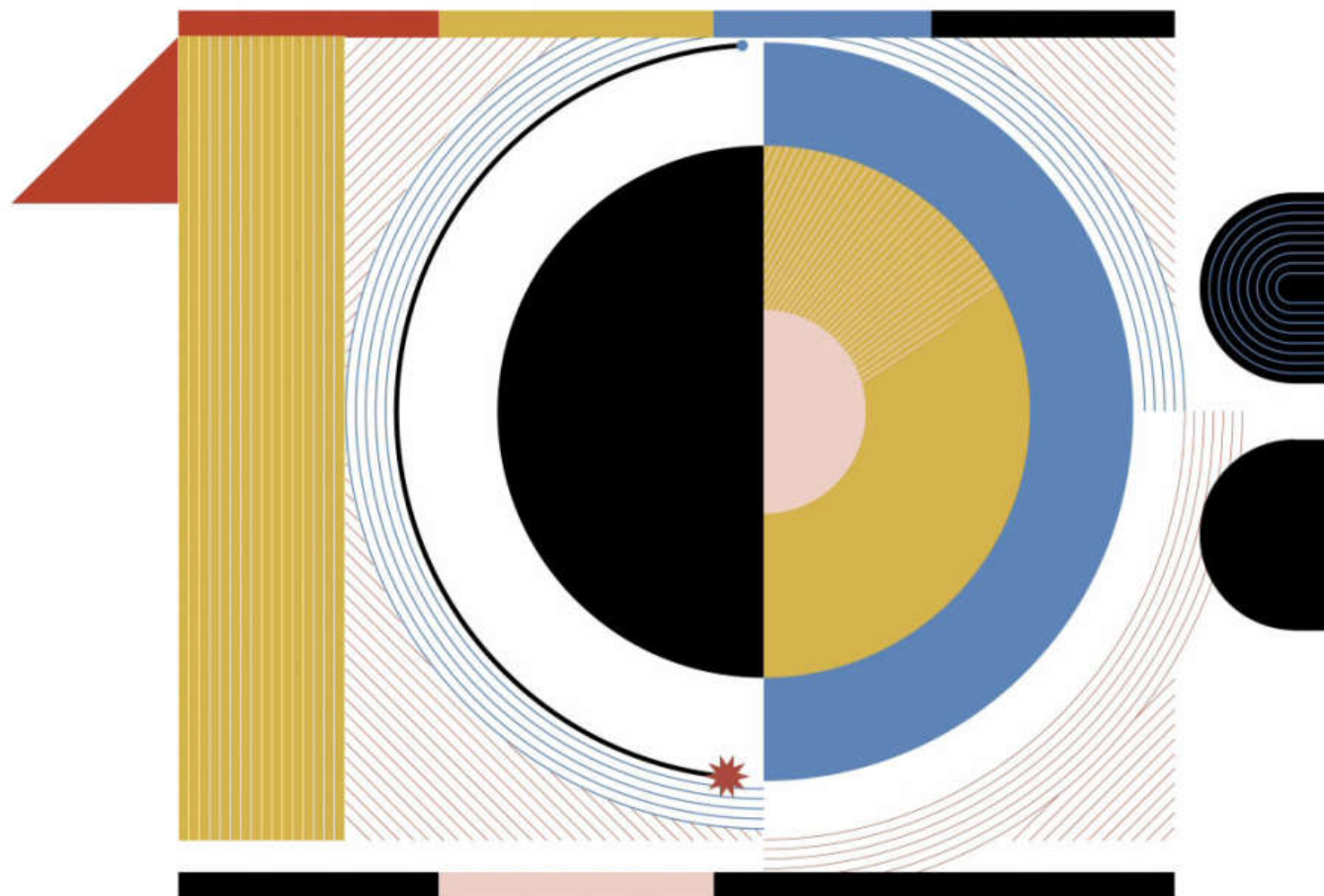
3D Fruit Printer, Dovetailed

This doesn't aim for traditional foods. Instead, it prints "bespoke fruits" in natural shapes, textures, and tastes. It drips flavoured liquid into calcium salt, which then forms in gelatinous fruit-shaped clusters, such as a raspberry.



Kathryn Whitehead

THE BRILLIANT



**FOR THE 14TH YEAR, *POPULAR SCIENCE* HONOURS
THE BRIGHTEST YOUNG MINDS RESHAPING SCIENCE,
ENGINEERING, AND THE WORLD**

by Veronique Greenwood & Cassandra Willyard



KATHRYN WHITEHEAD

Designs Drugs to Wipe Out Disease

/ AGE: 35

The human body is difficult territory to conquer, even for medicine: Many drugs have to enter the bloodstream, bypass the immune system, and arrive at a precise location within a designated cell. That's why Kathryn Whitehead, a chemical engineer at Carnegie Mellon University, is searching for the perfect vehicle: a nanoparticle that can shuttle new therapies directly to where they're most needed. Whitehead is focused on double-stranded bits of nucleic acid called small interfering RNAs (siRNAs). These molecules can block the production of many proteins that cause disease, and so can potentially treat everything from genetic disorders to viral infections. But siRNAs are unstable and difficult to deliver. While many researchers have tried encapsulating them with nanoparticles, they've struggled to find one that works successfully.

To identify the ideal delivery system, Whitehead employed a labour-intensive approach: Rather than tweaking the structure of a single nanoparticle bit by bit, she and her colleagues generated 5,000 novel ones, then tested the most promising in mice. "It sounds like a lot of work, and I suppose it was," she says. But the strategy enabled Whitehead to find nanoparticles she might have otherwise missed. "You just never know what's going to work well," she says.

By comparing the successes and failures, the team developed a model to predict the best particles. And they're now using their top candidate to develop therapies for non-Hodgkin lymphoma—drugs that target only cancer cells with specific mutations, hopefully ridding the body of disease while causing fewer harmful side effects.

Whitehead credits much of her scientific success to plain old perseverance; her lab's mascot is the honey badger, an animal known for its determination. "People look at me like I'm crazy when I say I tested thousands of materials," she says. "I think some others would have given up."

JACK GILBERT

Changes the World One Microbe at a Time / AGE: 38



Jack Gilbert wound up in microbiology because of ice cream. A food company hired him to look for substances to make frozen desserts smoother, a task that involved studying Antarctic bacteria. "It was a really noble cause!" he jokes. Now a microbiologist at Argonne National Laboratory and the University of Chicago, Gilbert samples bacteria from all kinds of ecosystems—both indoor and out—in order to better understand the unique roles they play. "I want the research I do to impact the way we manage the planet," Gilbert says.

In the pursuit of that goal, Gilbert's projects tackle problems as diverse as water treatment, crop productivity, and human disease. For example, he recently figured out why gut bacteria become more virulent after surgery—they lack

"I want the research I do to impact the way we manage the planet." —JACK GILBERT

JONATHAN PRUITT

Studies How (Spider) Societies Function / AGE: 29



Jonathan Pruitt's typical workday involves hours spent crouched in deserts and forests, observing the social lives of colony-building spiders. Like people, certain arachnids have different personalities—some are docile, some are aggressive—and Pruitt, a behavioural ecologist at the University of Pittsburgh, studies how these social traits affect survival. His findings provide the first evidence that individuals in the wild sometimes sacrifice their own genetic survival for the sake of the group—a topic of hot contention among biologists for 40 years.

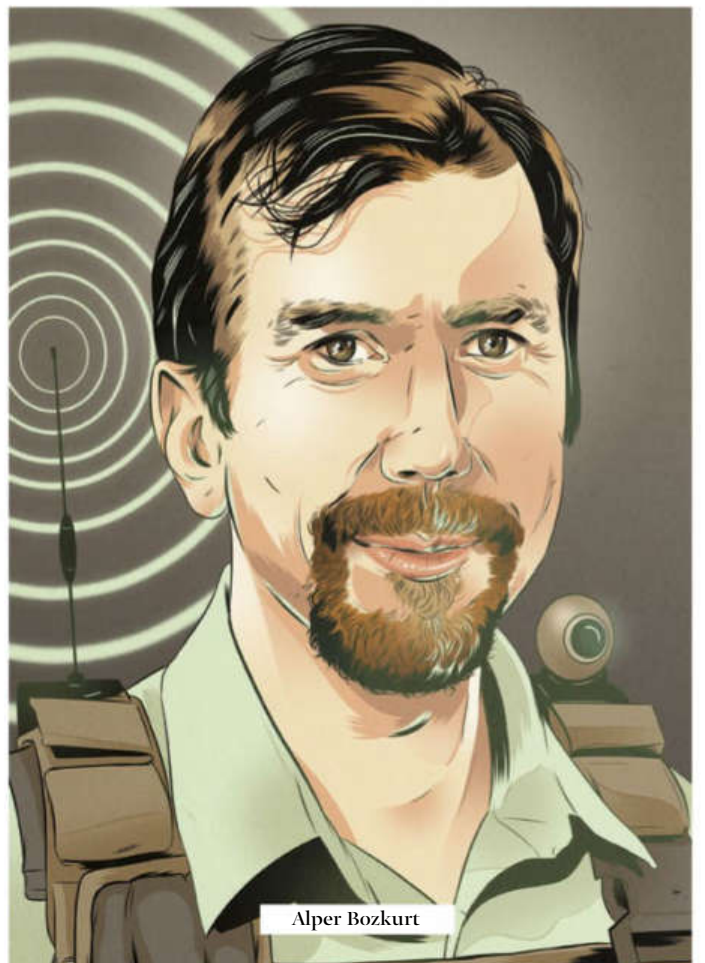
Life as a spider is risky. Each year 60 to 90 per cent of colonies collapse. "It's death, death, death—little carcasses blowing in the wind," Pruitt says. But he found that a colony's survival isn't purely a crapshoot: It depends on the ratio of docile to aggressive spiders. Colonies that have ample resources require more aggressive spiders to protect them, while colonies with few resources fare better with more docile spiders that don't waste energy fighting each other. If the ratio isn't optimal, individual spiders will adjust it by sabotaging their own offspring. Those spiders with an undesirable trait will lay fewer eggs—ensuring that the group endures even at the expense of their progeny.

Though evolutionary models suggested that such group selection must be occurring, no one had found solid proof. Many claimed looking for it was a waste of time. Having proved the skeptics wrong, Pruitt is now looking for other situations where group selection matters. The search has implications far beyond a single species. "If we can show that this is a robust result that we get in other systems," he says, "we can improve our understanding of how societies work."

phosphate, so giving patients phosphate can prevent post-surgical infections. Gilbert also found that people's homes take on the microbial signature of their bodies within 24 hours. He has a hunch those microbes can help repopulate the gut after a person has taken antibiotics.

To glean how microbes influence whole ecosystems, Gilbert's lab collects and models vast amounts of data—from homes, hospitals, rivers, and air. Gilbert and his colleagues have even set out to characterize all of the microbes on the planet. For the Earth Microbiome Project, his team has so far identified some 22 million species from samples sent in by hundreds of people. They'll analyze the resulting database to learn how these bacteria might be harnessed to improve people's lives.

Gilbert is quick to point out that he makes such potentially powerful discoveries because of his collaborations. He regularly works with more than 500 scientists. "If you're willing to put energy and enthusiasm into actually talking with people and understanding what their problems are," he says, "man! Everyone wants to work with you."





Alex Halderman



MARYAM SHANECHI

Decodes the Brain to Unlock Its Potential / AGE: 34

Maryam Shanechi used to study wireless communications systems. Now she investigates a far more complex network: the billions of neurons that make up the human brain. Shanechi, a neuroengineer at the University of Southern California, is trying to crack the neural code to develop better brain-machine interfaces. Existing devices simply translate the brain's electrical signals into movement, enabling paralysed people to move a computer cursor or a robotic arm. Shanechi applies control theory. In other words, she decodes neural activity from many parts of the brain to provide more-precise control. Next, she wants to translate those algorithms into signals the spinal cord can understand so paralysed patients can move their own limbs. Her team is already making headway. Last year, they processed the neural activity of a monkey and translated it into spinal stimulation that moved a second, sedated monkey's hand. The system doesn't work perfectly yet, but Shanechi has recently developed a more accurate model that tracks the brain's activity by the millisecond. She's also working on algorithms to help the brain self-regulate, providing stimulation that alleviates depression or post-traumatic stress disorder. Decoding mood is even more difficult than deciphering movement, but Shanechi says, "That's what makes it interesting."

ALEX HALDERMAN

Strengthens Democracy Using Software / AGE: 34

and challenged the public to do their best to hack it. It was an invitation that Alex Halderman, a computer-security expert at the University of Michigan, couldn't resist. "It's not every day that you're invited to hack into government computers without going to jail," he says.

In less than 48 hours, Halderman and his students gained complete control of the system and rigged it to play the Michigan fight song each time a vote was cast. The students were ecstatic, but Halderman, who has a long history of exposing cybersecurity weaknesses, takes a more sober view. "This is the foundation of democracy we're talking about," he says. Since then, Halderman has been working with governments that allow e-voting to make those systems more secure. At the request of a government whistleblower, he took part in the first independent examination of India's electronic voting system. "India's machines were fairly easy to tamper with," Halderman says. This past year, he and his students replicated the system in Estonia, where 25 per cent of votes are cast online, in their laboratory. They were able to introduce malware onto voters' computers and tamper with the server that produces the official count, proof that elections could be fixed.

Recently, Halderman has been developing software that exploits digital vulnerabilities for a different reason: It would allow citizens of countries like China and Iran to bypass government censors and access blocked sites. He released the newest version, called TapDance, last year and is talking with the US Department of State about working together to further advance it. The Internet can be leveraged to strengthen democracy, Halderman says. But to do so, "we're going to have to solve some of the hardest problems in computer security."

"This is the foundation of democracy we're talking about." —ALEX HALDERMAN

ALPER BOZKURT

Turns Animals into First Responders / AGE: 36

In 2009, Alper Bozkurt went to see *Up*, an animated movie that features a talking dog. An electrical engineer at North Carolina State University, he had been developing instruments to control cockroaches for search-and-rescue missions. But the movie gave him a new idea: What if he adapted his work for dogs?

Canines have long been used for search-and-rescue, but disaster zones can hamper their abilities. Because handlers rely on audio and visual cues, dogs must remain nearby, limiting the area they can cover. Bozkurt decided to build a cross-species communications system that defies distance. It enables humans and dogs to work together to save lives, even when separated by rubble.

The system consists of a harness fitted with sensors. Some track the dog's vital signs and others monitor its movement, conveying the poses a dog strikes when it picks up a particular scent. The animal can hear cues through a speaker on the harness; it can also feel them through a series of vibrating motors near its skin.

Ultimately, Bozkurt sees these cyberdogs as just one part of a more efficient search-and-rescue team, one that could include drones, robots, and cyber-cockroaches (roaches with electronic control systems). "We are at the dawn of a new era, where everything that can be interfaced electronically has started to interact," he says. "My vision is to fuse biological organisms with synthetic electronic systems."

BHASKAR KRISHNAMACHARI

Networks Cars for Safer Roads

/ AGE: 38

When Bhaskar Krishnamachari moved to Los Angeles, he hadn't spent much time thinking about cars. But one gloomy day, he caught a news report about a 194-car pileup. The fog hung so thick, drivers couldn't see the impending accident until it was too late. That disaster could have been avoided, Krishnamachari thought, if only cars could talk to one another. A network engineer at the University of Southern California in Los Angeles, Krishnamachari envisions a future in which cars are bilingual—able to converse with cell towers, as some can today, but also with other vehicles through digital short-range radios. A car slamming on its brakes could send a warning to any vehicle within half a block in milliseconds. Such a system could also be



The Brilliant 10


used to disseminate data that needs to reach many vehicles, such as software updates. Once a subset of cars downloads it through the cellular network, the data would spread to others nearby. Krishnamachari has been collaborating with General Motors since 2007 to develop vehicle-to-vehicle communication, and he has already tested it in a handful of cars. Last year, the team used GPS data from more than 600 taxis in Beijing to simulate how the system might work in a larger fleet. The US Department of Transportation also considers vehicle-to-vehicle communication the future: It recently announced plans to require such devices in new cars. The technology could help pave the way for self-driving cars, or even teams of robots doing remote exploration or disaster response. Krishnamachari is designing a system that's flexible. "When you build a network," he says, "you don't want to build it for specific applications."

DAVID KIPPING

Hunts for Moons Around Exoplanets / AGE: 31

In graduate school, David Kipping was hiking in the Himalayas when, staring up at the sky, he thought about how exoplanets are found—by detecting the change in brightness as it passes in front of a star. How would an exoplanet be affected if it had a moon, he wondered? His quest for an answer led him to pioneer a new field of study.

Kipping, now an astrophysicist at Columbia University, has developed a novel method to seek out exomoons. He and his colleagues sift through data from the Kepler telescope, and when they spot a promising exoplanet, they develop a mathematical model of what its orbit would look like if it had a moon pulling on it. They then compare that to orbital data. The sensitivity of the method should reveal satellites big enough to have an atmosphere and warm enough to support life. It could be that Earth-like moons are more common than Earth-like planets, which have turned out to be surprisingly rare. "It's actually quite plausible that we are the freaks of the universe living on a planet, and that most life lives on a moon," Kipping says.

At first, colleagues were skeptical that searching for exomoons was a good use of time. But since his first paper on the subject, others have joined the hunt. No exomoons have been found yet—Kipping's group ruled out 60 planets so far, and he hopes to look at 300 more in 2016. But if one of those candidates pans out, it could answer important questions about where moons come from and how planets form—and even inform the search for life beyond our solar system. 

ZEV GARTNER

Builds Tissues That Snap Together Like LEGO / AGE: 38

As a chemistry graduate student, Zev Gartner attended a biology class that changed his career. That's where he learned that the way cells are physically arranged in tissue can change how they behave—and whether they become malignant. "That concept was fascinating," he says. Gartner now builds tissue in his lab at the University of California at San Francisco, where he's a chemical biologist. By more accurately reproducing how cells grow in the body, he hopes to learn why the structure of tissue is so important to human health. Most methods for creating lab-grown tissue are imprecise, generating tiny samples that are all a bit different. Gartner developed a more elegant strategy: He exposes cells to pieces of sticky DNA that insert themselves into the cell membrane. Each of these DNA links attach only to others that complement its particular sequence. By varying the links, Gartner can assemble tissue layer by layer like LEGO, in exact structures. This allows him to make thousands of samples that are nearly identical, down to the specific arrangement of cells.

As a result, Gartner can control experiments to a degree previously impossible, exposing identical tissues to different therapies. He can also study how tissue changes with disease. Gartner suspects that when cells become cancerous, the way they attach to each other morphs. So recently he built breast tissue with two cell types to study how they interact. "If we understand how cells assemble," Gartner says, "we can understand what it is that lets a tissue break down and become metastatic"—a new understanding of cancer itself.

"The whole village was covered with grasshoppers. They had eaten even the bark off the trees." —ARIANNE CEASE

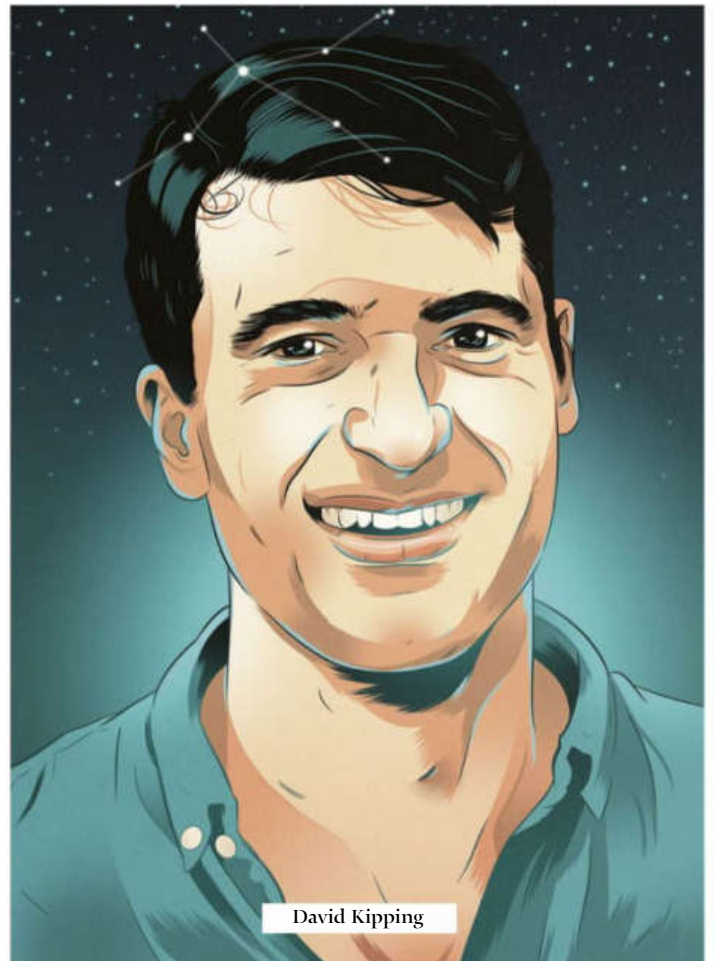
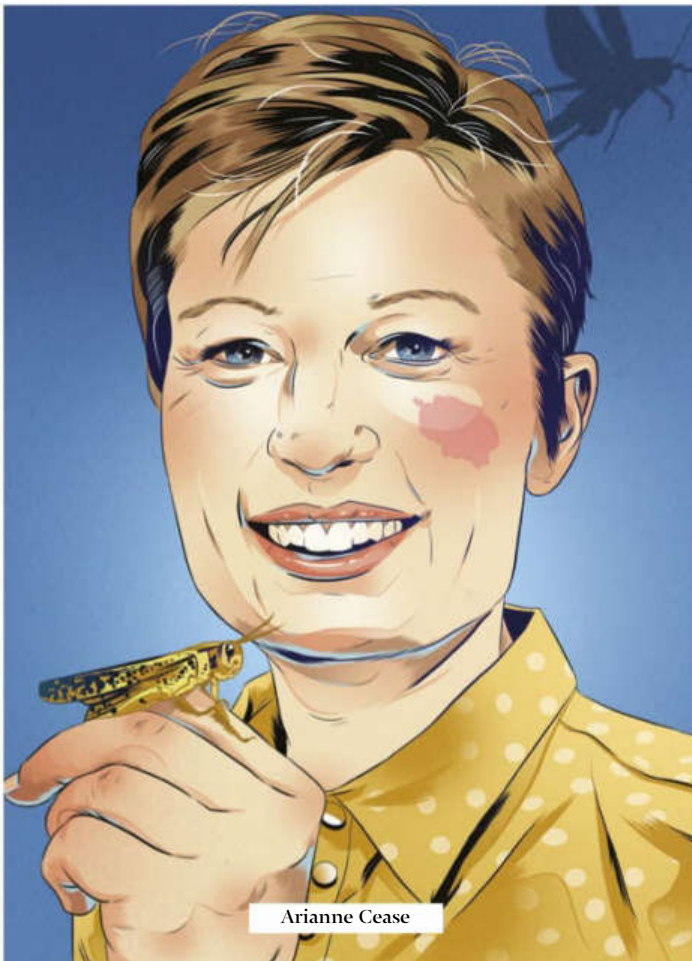
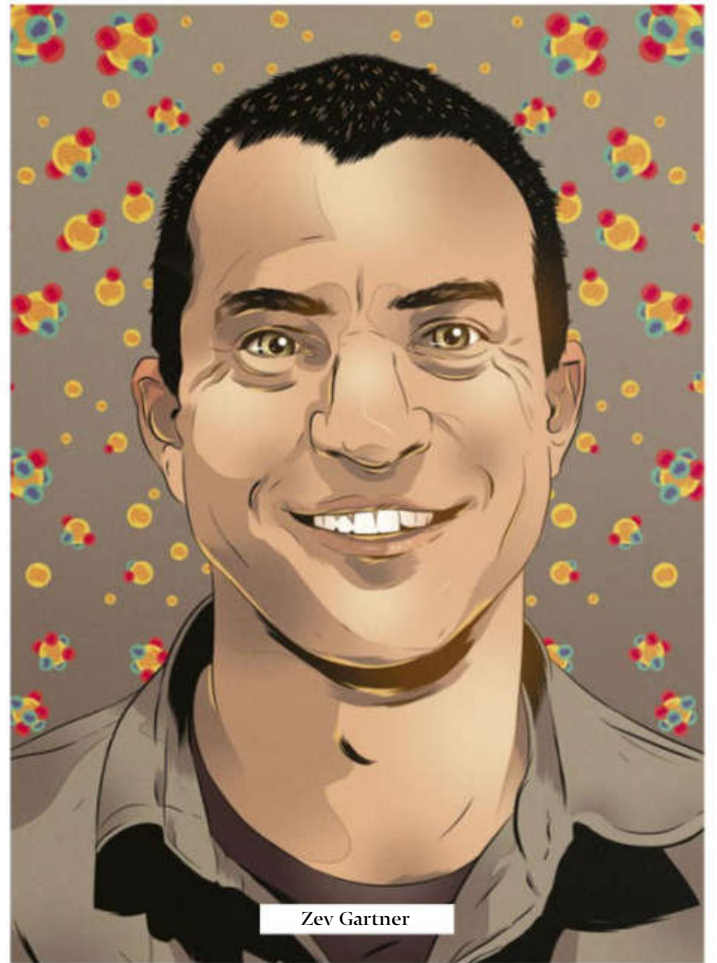
ARIANNE CEASE

Prevents Biblical Plagues with Modern Data / AGE: 33

In 2005, Arianne Cease was a Peace Corps volunteer in Senegal when disaster struck: Her small rural village was attacked by locusts, destroying a year's harvest. "The whole village was covered with them," she recalls. "They had eaten even the bark off the trees." Insect swarms regularly sweep across the globe. Cease saw that pesticides didn't seem to help. So when she left Senegal, she set out to find something that would.

Now a biologist at Arizona State University, Cease investigates what transforms individual locusts, which are harmless, into ravenous swarms that threaten the livelihoods of one in 10 people on the planet. She leads a research network that includes biologists, economists, and geographers who study a diverse range of possible factors, from the metabolism of a single locust to the international agreements that govern livestock markets. In China, her team made a surprising discovery: Overgrazing land can cause locusts to swarm by depleting the nitrogen level in the soil and grass. Locusts, it turns out, prefer a low-nitrogen diet, and in crowded conditions, that flips a switch in the insect's behavior. They also found that reducing farmers' herds—from nine sheep per hectare to six—prevented swarms from forming. Another benefit: The lower grazing density boosted the farmers' bottom lines by yielding healthier animals.

Cease is now working with government agencies in all three countries where she has projects—Senegal, China, and Australia—to identify practices that might help stop swarming, such as paying farmers not to overgraze. Traditional locust management involves attacking swarms as they form—a stop-gap solution at best. "We are trying to keep locusts at bay in the long term," she says.



LET'S TALK ABOUT

MARTIANS

We found the perfect excuse to geek out on exploring Mars—in science fiction and real life. And we invited the director of *The Martian* to join us.

INTERVIEW BY **Erik Sofge**



In *The Martian*, an astronaut (played by Matt Damon) is forced to survive alone on the Red Planet—here, simulated on a set in Budapest.



HOLLYWOOD

RARELY MAKES MOVIES LIKE *THE MARTIAN*.

It's a big-budget science-fiction film that's set in space but doesn't feature aliens, robots, or warp drives. The only villain is Mars itself, and the character who gets stranded there is a botanist (played by Matt Damon). *The Martian*, which opens on October 2, is about survival through science. To make that believable, director Ridley Scott strove to be accurate. We spoke with Scott and two consultants to his team—NASA's Dave Lavery and Andy Weir, the author of the book that inspired the film—about how they went about creating the next chapter in human space exploration.

What was it about *The Martian* that appealed to you?

SCOTT: I discovered really quietly that I'm a science-fiction fanatic. For many years after having directed *Blade Runner*, I kept missing it. That's what made me climb back in with *Prometheus*. When the phone rang, I was reading *Prometheus 2*.

With *The Martian*, I was fascinated by what NASA will have to do. You can't just go to Mars and land and say, "OK, let's build a house." You've got to get all that stuff up there. In effect, the first astronauts will have to be house builders. And how do you get it there? Do you drop it to the surface in balls and bounce it?

LAVERY: That's exactly the sort of thing we at NASA are constantly re-evaluating and redesigning as we prepare for the first human missions. Everything astronauts need to survive—from the atmospheric system to forks to eat with—will have to be provided. When you start wrapping your mind around that, you recognise it's a huge problem.

SCOTT: I guess spending billions to get a few plumbers up there is not very romantic, is it? You better have the water running before you get up there.

LAVERY: Our current thinking is to have the habitat placed and in operation before the astronauts ever leave Earth. Andy gets that right.

more like: "OK, well, this thing broke. That's why we have four independent backups."

SCOTT: The book has so much research on how to survive anywhere. That was really the lifeblood of the story and the screenplay—the idea that this guy is Robinson Crusoe, as I saw it. How does he pull himself together when he gets stranded? It's intriguing to think about what you would do in that situation, given what's at your fingertips. It's all there to survive, provided you don't panic. Gradually the nuts and bolts come together through the mind of Mark Watney [Damon's character].

WEIR: Drew [Goddard, the screenwriter] and I went back and forth a lot on the screenplay. I really appreciate how close you guys stayed to it. I was surprised.

SCOTT: We also talked to NASA quite often. Our production designer visited and saw stuff like the new suits. I don't like your suits, by the way, dude. Jesus Christ, the puffiness. I think you're going to like our suits much better [laughs].

LAVERY: We have an ongoing program to try to understand what Mars suits will be like. One thing we realised a long time ago is that the Apollo-generation suits just are not suitable for a Martian environment. We're doing whatever we can to make the suits smaller and lighter, more flexible, more comfortable. The Apollo suits, for what we had at the time, were wonderful. But they are not going to work over weeks or months for long-term exploration.

SCOTT: I love the big white suits. We use those at the end. They're spectacular.

How realistic is *The Martian*?

LAVERY: One of the things that impressed me in the book is the effort to be technically accurate—correct about what resources are available, how problems would get solved. Even small details about the other spacecraft, like what might be available to scavenge and repurpose. It's obvious that a lot of research went into it. And I was happy to see that same treatment in the script. I was contacted several different times by Ridley's crew about, for example, what the *Sojourner* rover

Our roundtable



Ridley Scott,
director of the film
The Martian



Andy Weir,
author of
The Martian
sci-fi novel



Dave Lavery,
program executive
for solar system
exploration at NASA

Is it challenging to remain scientifically accurate?

WEIR: It's hard to tell a compelling story and remain true to science, especially if you're talking about the real space program. Frankly, NASA's whole job is to keep exciting things from happening—to make sure there's not a panicked, "Oh my god we're gonna die" situation. It's

Let's Talk About Martians

Scott filmed certain scenes in Jordan's Wadi Rum desert; the Mars-like landscape didn't require special effects.

actually looked like. Where would things be positioned?

SCOTT: We reproduced the *Sojourner* and its mate. The thing is so beautiful. Why not just reproduce it?

LAVERY: The very first Mars mission that I worked on as a flight project was the *Sojourner* rover.

SCOTT: My god.

LAVERY: To be able to go back and talk about that and what it actually had on board was a lot of fun.

Were some details sacrificed for the sake of story?

WEIR: The two biggest inaccuracies in the book were: One, the inertia of a Martian sandstorm isn't large enough to cause damage to anything. And two, I do only a sort of hand-wavy lip service to radiation protection. I just vaguely say, "Oh yeah, all this stuff is shielded from radiation." But that's actually a huge problem in real life, and there's no easy solution.

SCOTT: I have him wrapping his radioactive generator in space foil like a giant Christmas present.

WEIR: [Laughs] That's awesome. I kept getting these questions filtered to me through a bunch of people, where Ridley was saying, "Hey, wait a minute, a dust storm on Mars would not cause this kind of damage." And I was like, "Yeah, you're right." I had an alternate beginning in mind for the book that I ditched because it wasn't as exciting. It was an engine-test failure. I told Drew I could write that up with all the technical details. And he was like: "No, everybody is happy with the sandstorm. It looks really cool."

SCOTT: The storm is massive. We won't be reshooting that.

How do you think people will perceive space exploration after watching the movie?

LAVERY: I've been thinking about that quite a bit. The idea that this could be one of those go-to films that help people understand the



realities of space exploration—in the same way, for example, *Apollo 13* did—is an exciting prospect. The book and the film also tell the human story, and that's important. The way the characters react and deal with enormous technical problems is very accurate.

I do have one question, related to that, for Andy. I was absolutely fascinated by the idea that Watney's skill centred on his role as a botanist. And I'm curious, as you developed the idea, did you start with, "Hey, I've got a botanist on Mars; how does he survive?" Or did you start with, "I've got a whole bunch of problems, and the perfect guy to solve them is a botanist?"

WEIR: The latter. If you're going to be on Mars for a long time, there's no way to survive without growing food. And rather than try to convince the reader that a pilot could successfully grow a bunch of crops in an adverse environment, I thought, "Oh, I can say his scientific role is a botanist, and then no one will question anything plant-related he does from then on, right?"

SCOTT: We did an experiment to see how you might really grow food on Mars so we could show it as accurately as possible. We were growing spuds in a warehouse under lights like you'd grow marijuana [laughs].

LAVERY: I think the movie will reinforce the idea that this is something achievable. People will get an appreciation for what the astronaut experience is like. But I think even beyond that, people are also going to have a newfound respect for botanists.

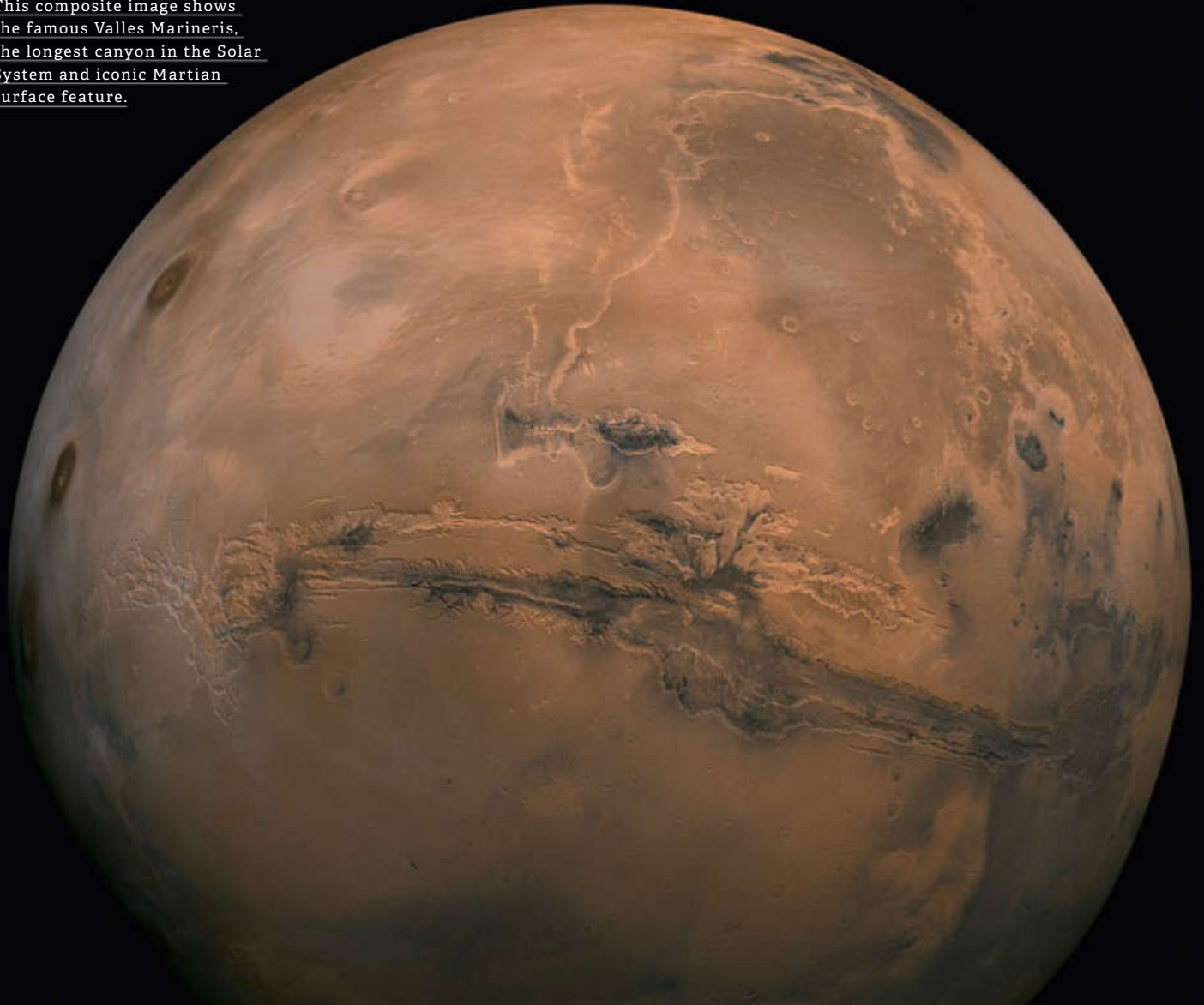
Would you ever go to Mars?

SCOTT: I love the Earth too much. And I think the endless journey would get me down. Astronauts have to be perfectly balanced psychologically. I tip my hat to them.

WEIR: Science fiction and popular culture have dramatically undersold the complexity of getting humans to Mars. People think: It'll be harder than the Apollo program but, c'mon, leaving Earth and going to another place, how hard can it be? Well, many, many orders of magnitude harder. That takes a level of bravery that is well beyond anything I would be willing to do.

LAVERY: I would actually want to go to Mars, with one big caveat: I would want to make damn sure that I get to come back [laughs]. I'm not interested in a one-way trip. But if I can come back, yeah, I would do it in a heartbeat. 🇺🇸

This composite image shows the famous Valles Marineris, the longest canyon in the Solar System and iconic Martian surface feature.



FOR LOVE OF A RED PLANET

The ongoing story of the human exploration of Mars

From the time we invented telescopes powerful enough to make out features on the Martian surface, humans have been fascinated with the fourth rock from the Sun. We've launched more landers and orbiters at this dusty little world than any other planet, and odds are it will be our first home-away-from-home. Here's a brief history covering the highs - and lows - of our love affair with Mars.

By ANTHONY FORDHAM

EARLY OBSERVATIONS

IN THE CENTURIES preceding the invention of spaceflight, humans peered at Mars through telescopes of variable quality. Some of the first observations showed apparent colour changes on the surface, and hints of straight lines and other geometric forms.

For a brief period, a select group of publicity-happy scientists suggested Mars had seasonal vegetation and was inhabited. The

infamous Percival Lowell published maps of a Mars criss-crossed with canals.

Even at the time though, few in the wider scientific community believed our planetary neighbour to be an inhabited world. Eventually, better telescopes revealed the truth: Mars was probably dusty and dry, and the colour changes were vast dust-storms sweeping the planet.

1960-1979 THE SPACE RACE ERA

AS WITH MUCH OF what they did in space during these decades, the US and USSR competed to first flyby, orbit and then land a probe on Mars. The US had some success. The USSR... less so.

NASA: MARINER AND VIKING PROGRAMS

Part of the USSR's misfortune (see next page) could be put down to the Soviet obsession with beating the US to a Martian flyby. Things were looking good for the reds when Mariner 3 failed to launch properly in 1964, but communist hearts must have sunk when Mariner 4 successfully launched and flew past Mars on 14 July 1965,

sending back the first grainy black-and-white image of Mars - in fact the first close-up photograph of another planet ever taken.

Mariner 6 and Mariner 7 flew past Mars in 1969, sending back even more valuable data. Then, also in 1971 but slightly ahead of the USSR's Mars 2 and 3 probes, Mariner 9 entered Martian orbit. At the time, a vast dust storm shrouded the entire planet,

and the operators on Earth anxiously waited for the weather to clear. This was when humans discovered the Solar System's highest mountain - the extinct volcano Olympus Mons.

Four years later, the Viking program launched two spacecraft, each with an orbiter and a lander. Unlike the frenetic earlier shots, the Viking orbiters arrived at Mars in 1976 and orbited the planet for a month each before releasing their landers. This allowed NASA scientists to select the best landing sites. Viking 1 landed on 20 July 1976, and Viking 2 landed on 3 September.

The results of these missions provided the first colour panoramas of the Martian surface, created detailed maps, and basically provided all human knowledge of the red planet from the mid-1970s up until 2000.

▼ Science personality (and actual proper scientist) Carl Sagan poses next to one of the Viking landers.



NON TRIVIAL TRIP

Getting to Mars is a significant engineering challenge, and on current odds, two-thirds of all spacecraft sent there fail before completing their missions. Many simply disappear on-route, others are damaged on landing, while others fail due to computer glitches or dust build-up on solar panels. And yet, some Mars missions have unexpected success: NASA's Spirit and Opportunity rovers worked for years longer than expected.

A History of Mars

1960-1979
THE SPACE
RACE ERA

USSR: MARS PROGRAM

The Soviet Mars program (yep, it was just called “the Mars program”) had very limited success during this period. Their first four missions failed before even leaving earth orbit. The Mars 1M spacecraft didn’t reach orbit, the Mars 3MV probes couldn’t leave Earth orbit due to upper stage rocket problems, and the Mars 2M ships were destroyed during launch.

The Mars 4M mission, with two identical spacecraft called Mars 2 and Mars 3, became the first to reach the surface of Mars in late 1971. But a series of system malfunctions saw one lander crash and the other touchdown softly but stop working after just 14.5 seconds. Yet the orbiters continued their mission and sent back huge amounts of data. These missions helped create the first relief maps of Mars and gave scientists important information about the planet’s gravity and very weak magnetic field.

Later Soviet missions fared little better. Faulty transistors, bad rockets, on-board computer failures all contributed to a high rate of mission failure.



▲ The Soviet probe Mars 3 (this is a model in a Russian museum) actually made it to the surface of the planet and sent back data... for a handful of seconds.

RUSSIAN SUCCESS STORY

Think the Soviets had it rough with all those Mars failures? The USSR had better luck on Venus, landing 10 probes on the surface and floating 11 in the atmosphere under balloons. USSR gets the gong for first soft landing on another planet (Venera 7, 15/12/1970) and the first return of images from a planetary surface (Venera 9, 8/6/1975). Space is hard.

1980-2000 THE MISSION FAILURE ERA

THE NEXT 20 YEARS of Martian exploration were not humanity’s finest. In 1988, the Soviets lost Phobos 1 on the way to Mars, and Phobos 2 snapped a few (still valuable) photos before failing to release its lander.

NASA lost Mars Observer in 1993, just three days before it was due to orbit the Red Planet. Then the USSR lost a mission called Mars 96 on launch in 1996.

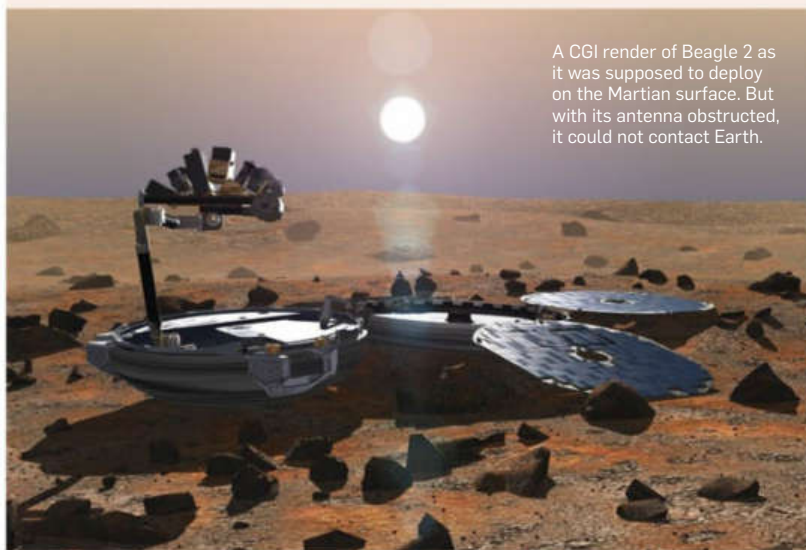
Next to fail was the infamous Mars Climate Orbiter. Infamous because NASA lost contact with its probe on 23 September 1999 as it went into orbital insertion. Computer software on Earth had been designed to work in imperial

1990s. Nozomi was designed to study the upper atmosphere, but suffered the most feared fate of ships in space: it made course corrections that left it short of fuel. A mission redesign could have salvaged the probe, but powerful solar flares in 2002 damaged the spacecraft further.

Japanese scientists made one further course correction to Nozomi, to prevent it from crashing into Mars. They were concerned it could contaminate the Red Planet with bacteria from Earth, since the spacecraft had not been properly sterilised like other Mars landers.

As the Millennium rolled around, Britain tried to land a sophisticated probe called Beagle 2 on the planet. Hitching a ride on board the European Space Agency’s 2003 Mars Express mission, Beagle 2 separated successfully but then refused to talk back after landing. British scientists kept trying until February 2004 before declaring the mission lost.

Amazingly, 11 years later in January 2015, NASA’s Mars Reconnaissance Orbiter spotted Beagle 2 intact on the surface. Apparently, two of the probe’s solar panels failed to unfold, obscuring its main communications antenna. Per-



A CGI render of Beagle 2 as it was supposed to deploy on the Martian surface. But with its antenna obstructed, it could not contact Earth.

pound-seconds instead of metric Newton-seconds. This US obsession with old-school measurement caused the spacecraft to enter the Martian atmosphere too fast, and it broke up. Just two months later NASA also crashed the Mars Polar Lander, possibly due to a foul-up with the probe’s engine.

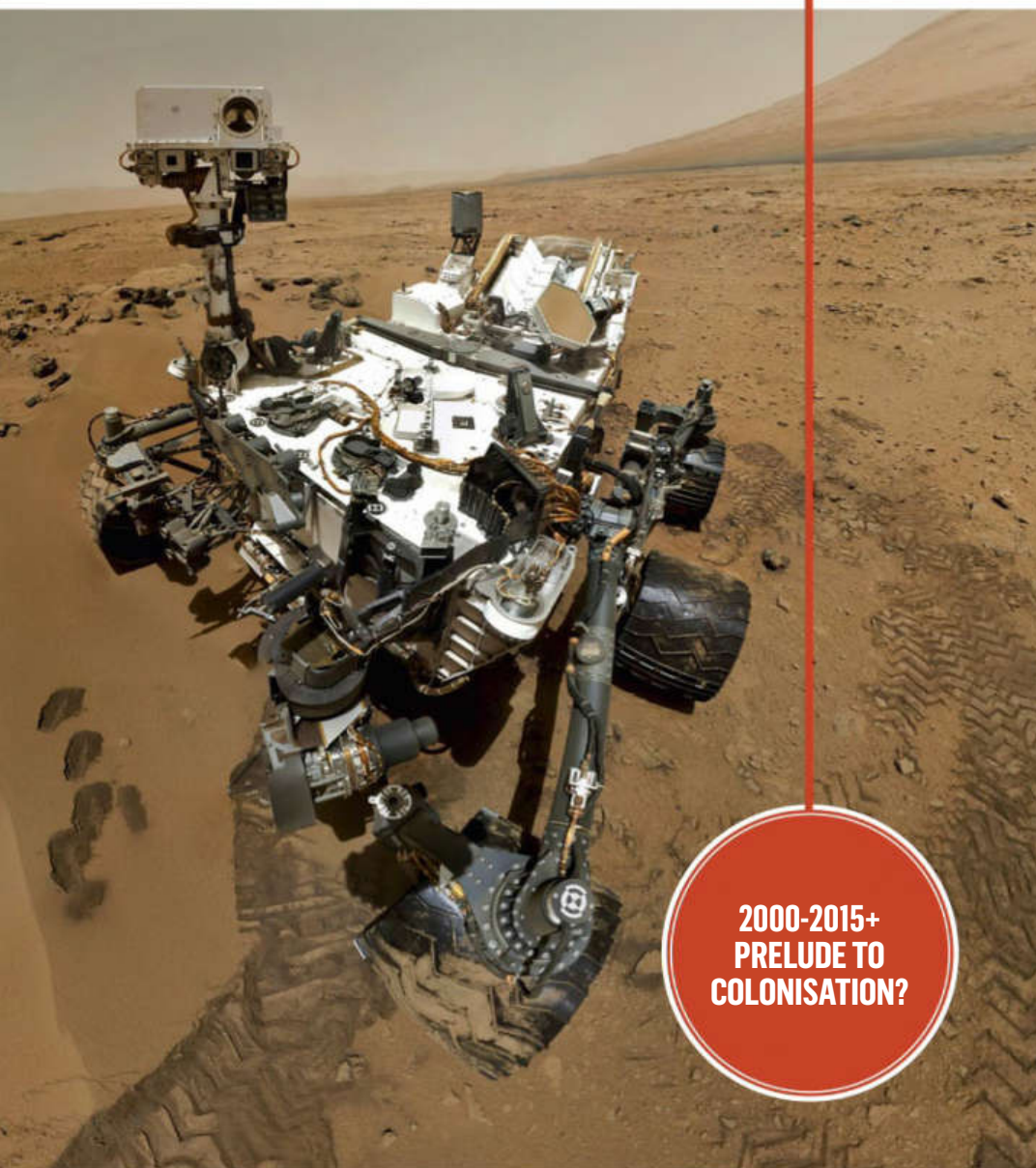
Japan too suffered the sting of Mars-related failure in the late

haps one day humans will investigate this relic of early exploration on site.

The latest prominent Mars-shot failure was of course the Russian Fobos-Grunt. An ambitious mission, intended to land on and return samples from Mars’ moon Phobos, it instead became stranded in low Earth orbit. Much excitement surrounded its uncontrolled re-entry and fiery demise over the Pacific ocean in January 2012.

A History of Mars

▼ Curiosity snaps a selfie somewhere in Gale Crater. With its superior cameras, we can now see Mars isn't so much the Red Planet as the Brown But Slightly Red I Guess Planet. The rover's mission has been extended indefinitely.



2000-2015+
PRELUDE TO
COLONISATION?

WINDOWS OF OPPORTUNITY

Getting to Mars is all about managing energy. As both planets move around their orbits, there's an ideal time to send a mission, when Earth and Mars are at their closest. This happens every two years and two months. And every 16 years there's an even lower-energy window available.

STARTING THE LATE 1990s and continuing until today, a series of successful missions have vastly improved our knowledge of Mars. Today, the Martian sky is filled with orbiters, and rovers crawl across the surface studying geography, the atmosphere and more. It's a busy place.

NASA's Mars Pathfinder landed in 1997, and unloaded Sojourner - a small six-wheeled rover, not much bigger than a toy. As well as performing many scientific experiments, Pathfinder (as its name suggests) tested a bunch of technologies which were used by later missions, including the famous Spirit and Opportunity rovers.

When NASA's next mission, the Mars Global

Surveyor, achieved Martian orbit on 12 September 1997, it became the first fully successful Mars mission in nearly 20 years. It mapped Mars from a low-altitude orbit, taking an entire Martian year (two Earth years) to finish the job. Mars Global Surveyor returned more data on Mars than all the previous missions put together. It kept up communication with Earth until November 2006.

In 2003, a new age of Martian exploration dawned. The Mars Exploration Rover mission delivered Spirit and Opportunity to the surface, and their work continues to this day. Both probes have received mission extension after mission extension: Initially intended to operate for just 90 Martian days they are still on the job.


Spirit became stuck in soft sand in 2009, and was retasked as a stationary science platform. Opportunity trundles on, and in 2014 began a new mission, working with its much bigger brother Curiosity on the search for evidence of Martian life.

Ah yes, Curiosity. The first spacecraft with its own Twitter account. Launched in 2011, it landed on Mars under a positively sci-fi "sky crane" in August 2012, with much social media fanfare and a dedicated website that showed a virtual recreation of the landing, live. An impressive detail: it landed just 2.4km away from the bullseye of its intended target, after travelling 563 million kilometres.

Curiosity was built to last just 687 days, but so far has clocked in for over 1000 days. Its mission was extended indefinitely in December 2012.

This car-sized rover, one of the biggest ever, now begins the search for life - or evidence of past life - on Mars, and will also conduct many of the experiments needed before humans can visit.

NASA hopes to launch another rover in 2020, built on the same proven platform as Curiosity but with a different scientific payload. After that, who knows? Humans may follow. An orbital mission at first, perhaps, with landings to come later.

What's certain is that when it comes to Mars, we've barely begun. The challenge of colonising this rocky little world is immense, perhaps the hardest thing ever. But if those plucky little robot rovers are any kind of example, it's a challenge we'll rise to, and overcome. 

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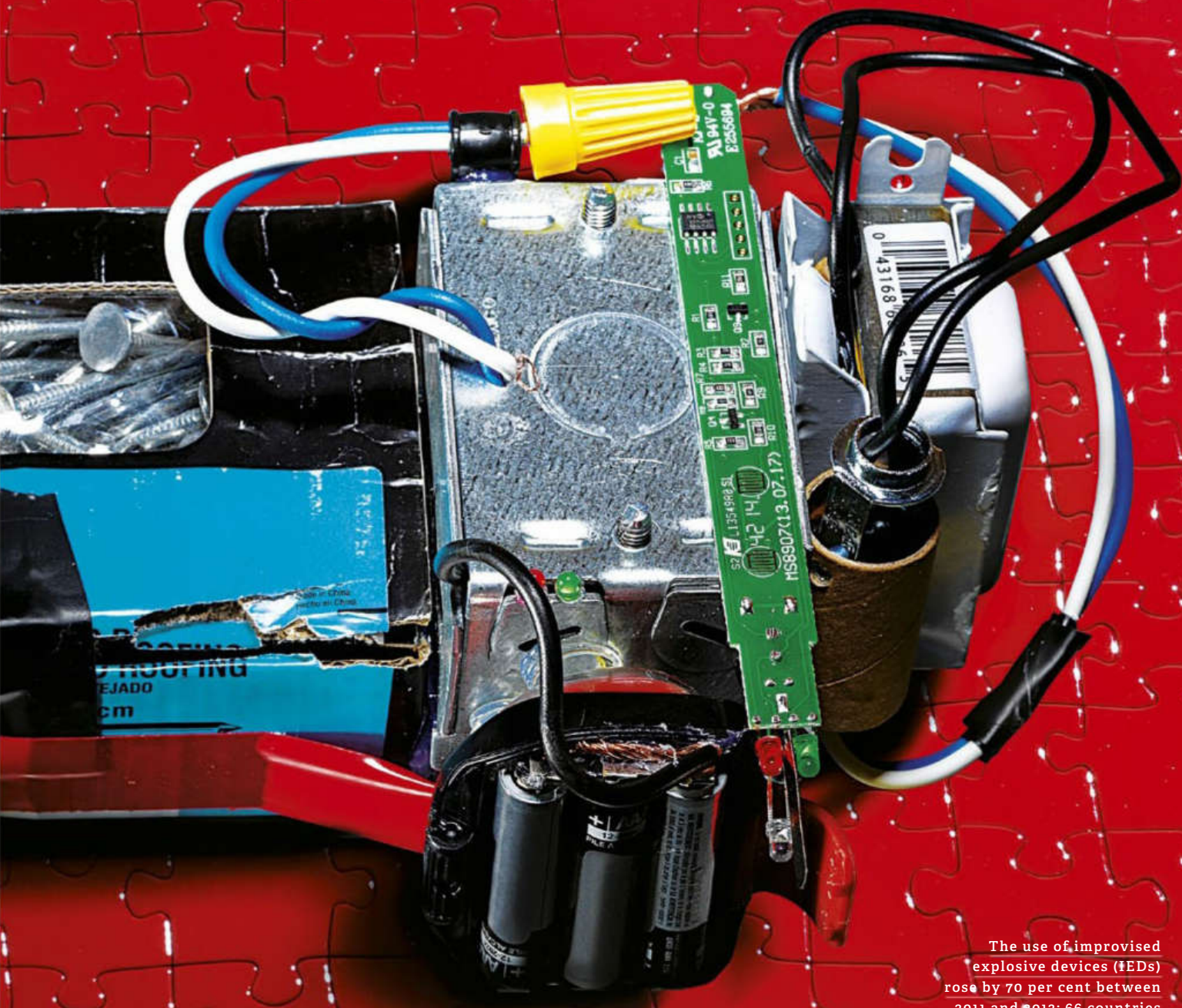
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TO CATCH A BOMB- MAKER

In April 2009, an Iraqi refugee arrived in America ready to make a new life. No one suspected he was an Al-Qaeda operative. This is the story of a little-known FBI forensics lab and how it changed the war on terror.

By Clay Dillow





The use of improvised explosive devices (IEDs) rose by 70 per cent between 2011 and 2013; 66 countries suffered attacks, some on a near-daily basis.

1.



2.



THE INSURGENT- BEGAN WITH A CORDLESS- PHONE—

one of the knockoffs of a Chinese-built Senao so popular in northern Iraq. Hunched over a worktable somewhere near the refinery town of Baiji, about 250 km north of Baghdad, he methodically worked through a series of steps by now both familiar and frighteningly simple.

Loosen the screws on the base station. Remove the plastic casing, rip out the power cord, and replace it with a battery. Rewire the phone's page function to an external relay switch, then connect the relay to a battery and any mix of violent chemistry—plastic jugs full of diesel and fertiliser, a pressure cooker packed with homemade explosives, one of the many artillery shells available in post-invasion Iraq. When complete, pressing the page button on the phone's handset—even from kilometres away—will flip the relay and trigger the bomb.

During the conflicts in Iraq and Afghanistan, improvised explosive devices (IEDs) became the single deadliest weapons on the battlefield. In Iraq alone they accounted for between half and two-thirds of all US wartime casualties and killed tens of thousands of civilians. They have now become a staple of insurgencies worldwide. But back in 2005—when the bombmaker sat poring over his Senao—the US military was only beginning to understand the threat they posed.

In the waning days of August that year, insurgents concealed the modified Senao in a gravel heap south of Baiji. They then wired it to three artillery shells buried in a road several metres away. The bomb was presumably meant for one of the patrols that frequented the route, but on Sept. 1, 2005, US forces discovered it before it detonated. A bomb-disposal team neutralised the explosives and then packed the Senao into a crate destined for a little-known FBI forensics lab operating out of a parking garage in northern Virginia. No one knew at the time that the IED was anything more than just another in a flood of roadside bombs. Instead it would end up unmasking a terrorist and helping FBI analysts pioneer techniques that have foiled criminal plots around the globe.

In the heavily wooded grounds of Marine Corps Base Quantico in eastern Virginia, special agent Greg Carl leads the way into an imposing building and down a windowless hallway. Swinging open a pass-code-secured metal door, he steps into the warehouse that contains the FBI's Terrorist Explosive Device Analytical Centre (TEDAC). A row of white boxes, each 1200 by 1200 mm, runs down the centre of the room. Others line the 35-metre-long walls, each one bar-coded, inventoried, and packed with IEDs.

Carl is TEDAC's director, and this space—tucked in the bowels of a garage adjacent to the FBI's main forensics lab—is intake. More than 100,000 IEDs have passed through here since the lab opened in 2003. Some arrive inert but intact, others in post-detonation fragments. Lab technicians analyse each one and catalogue it in TEDAC's database, creating what has become the world's largest bomb library.

To Catch a Bombmaker



1. IEDs take many different forms: big or small, wireless or analogue. The FBI's TEDAC lab serves as a clearing house for them all.

2. Some IEDs arrive at TEDAC as bomb or trigger fragments, while others arrive as complete, albeit neutralised, devices.

3. Analysts photograph each IED in ultra high resolution and store that image in a digital reference library.

In the field, an IED is an anonymous threat. But at TEDAC, it gains context. By comparing physical evidence along with the IED's location, design, and materials, investigators can draw connections between bombs and bombmakers. They might trace multiple IEDs to a single factory—or even a single individual. They might identify new trends or techniques. And they can continue to analyse evidence for years, tracing bombmakers and their apprentices through time.

“Up until TEDAC, the Department of Defence didn't understand the benefit of having forensics on the battlefield,” Carl says. “But fighting insurgencies is more like fighting organised crime. It's a conspiracy.”

In 12 years, analysts using TEDAC data have tied more than 2,700 suspects to possible terrorist activities, and nominated more than 350 to the terrorist watchlist. The lab has collected and shared 80,000 fingerprints with law-enforcement agencies around the globe. It has been so successful and grown so rapidly that this summer the FBI began moving 250 TEDAC staffers out of the improvised headquarters into a \$132 million facility in Huntsville, Alabama.

That's today. In 2003, the centre looked much more like a startup. The focus was mostly on Iraq and Afghanistan, and the staff was composed of just a few dozen analysts—many borrowed from other FBI labs. Then the Iraqi insurgency took off. What started as a few IED deliveries a month turned into hundreds, then as many as 2,400. That's how TEDAC ended up working out of a parking garage, Carl says. The lab had to grab whatever space it could.

By the time the Baiji bomb arrived in late 2005, TEDAC's analysts were mired in a massive backlog of evidence. Tens of thousands of devices awaited examination. The Baiji bomb was still among them when, in 2010, an unusual request landed on the desk of forensic scientist Katie Suchma. The query had originated not in Kabul or Kirkuk but in Kentucky. FBI agents there had become increasingly nervous that an Iraqi refugee recently resettled in the college town of Bowling Green was actually an operative for Al-Qaeda in Iraq (AQI). They made a simple but urgent request: Tell us everything you can find out about Waad Ramadan Alwan.

“FIGHTING INSURGENCIES IS MORE LIKE FIGHTING ORGANISED CRIME. IT'S A CONSPIRACY.”

In early 2007, the US State Department launched an ambitious program to resettle tens of thousands of Iraqis—many of whom served as interpreters or fixers for US forces and faced reprisals from militant groups—to new homes in the US. Waad Ramadan Alwan was among those who applied. After passing a State Department vetting process, he received a visa and assistance in moving to Kentucky in April 2009.

In Bowling Green, Alwan lived with his wife in a simple apartment and worked at a chicken-processing plant. By all appearances, he led a normal life. So when the FBI received a tip in September 2009 indicating that Alwan might be an AQI member, it wasn't immediately clear that the intelligence—the details of which the FBI won't discuss—was accurate.

Agents at the FBI's Louisville field office mounted some standard surveillance but soon moved on to a full-blown investigation. They

arranged an introduction between Alwan and an FBI informant posing as a fellow refugee sympathetic to the AQI cause. Alwan was a little cagey at first, but by early 2010, something changed. He began to talk about his past.

“He starts saying things that make the hair stand up on the back of your neck,” says FBI supervisory special agent Tim Beam, of the Louisville field office. “He starts talking about participating in attacks on US troops in Iraq. He's talking about building bombs.”

While Alwan's bragging seemed to validate the FBI's intelligence, agents couldn't be sure: Was he a hardened AQI militant responsible for attacks on US soldiers abroad or simply a boastful Iraqi looking to impress a new friend? If he was AQI,

1.



2.



was he working alone or as part of a network of militants secretly plotting attacks on US soil?

In order to find out, FBI agents set up a sting operation. The informant told Alwan he had friends in the US willing to send cash and weapons to insurgents in Iraq, but he needed someone with contacts to facilitate. Alwan agreed to play middleman. In the first half of 2010, Alwan made regular trips to a storage unit in Bowling Green in which hidden cameras captured him preparing to ship a litany of weapons—Russian PK-model light machine guns, rocket-propelled grenades, sniper rifles, C-4 explosives, and even shoulder-fired Stinger anti-aircraft missiles. (All of the weapons were rendered inert by the FBI before being furnished, and the bureau maintains no money or weapons ever left the country.)

With that evidence, agents had grounds to charge Alwan with material support of a terrorist group. But by late spring of 2010, investigators were increasingly convinced that Alwan had indeed acted against US troops in Iraq. In taped conversations, he boasted of building dozens of IEDs. He said he'd fired on US troops with a sniper rifle. FBI agents claim he said that he'd had American soldiers "for lunch and dinner."

The FBI wanted justice for those soldiers. Moreover, if agents could prove Alwan was responsible for attacks on US forces, they could bring far more serious charges against him—charges that could make him a valuable intelligence source during plea negotiations. But finding hard evidence against Alwan years after the fact—and in a war zone on the other side of the world—was a monumental challenge. Agents reached out to TEDAC for help.

When an IED arrives at TEDAC, it undergoes something of an entrance exam. First, a lab technician unpacks the device and creates an examination plan based on its type and the type of evidence that might be salvageable. Then techs photograph each IED, inside and out, at resolutions so high that individual characters stamped on microchip components are visible. Those images go into TEDAC's database, where investigators or bomb technicians at partner

agencies around the world can access them.

That visual record is vital, Carl says. The way a bombmaker has soldered a joint or twisted a wire can reveal if he or she is left- or right-handed. Certain techniques or constructions can serve as a signature for an individual or a group of bombmakers. "Maybe we can't definitively say, 'This person built this IED,'" Carl says, "but we can tie it back to a certain bomb factory."

All devices then move on to other stages of analysis. Some go to the FBI's tool-marks lab, where forensics experts look for unique, microscopic markings left by specific tools or machines. If the bomb remains wholly or partially intact, engineering specialists break down its construction, logging those distinct aspects that could serve as a bombmaker's signature.

Biometrics specialists scour devices for fingerprints or trace DNA that could tie an IED to bombmakers.

When Katie Suchma received the request to hunt for intelligence about Alwan in 2010, the majority of TEDAC's inventory had not been through advanced stages of analysis. "They wanted us to run this one guy's fingerprints against everything we had," Suchma says. "It was a needle in a haystack."

THE TERRORIST BOASTED OF BUILDING DOZENS OF IEDS. HE SAID HE'D HAD AMERICAN SOLDIERS FOR LUNCH.

Slowly she and her team of more than 35 analysts began to winnow down the search options. Through the informant, the FBI had a rough idea of where Alwan was between 2004 and 2006, so that limited the number of target IEDs by geography. The team pulled 170 relevant boxes of evidence that represented 1,300 IED events and got to work. The FBI also had copies of Alwan's fingerprints, so the TEDAC team focused on recovering physical evidence when they could.

In November, agents caught a break when Alwan offered to show the FBI's informant how to build an IED. Alwan drew a few sketches detailed enough to give TEDAC's analysts insight into the type of device they were looking for. In December, the search narrowed further when FBI intelligence analysts digging into Alwan's past told TEDAC to focus on bombs from in and around Baiji.

By this point, Suchma and her team were already closing in, and in January, she sent a message to FBI headquarters in Washington DC. They

To Catch a Bombmaker



1. Neutralised IEDs or IED fragments arrive at TEDAC as criminal evidence.
2. Today no evidence waits longer than 150 days for processing.
3. Greg Carl, the director of TEDAC, is transitioning the lab from its focus on Iraq and Afghanistan to a "rest-of-the-world" mission.

could stop wondering about Alwan. Two fingerprints lifted from an IED recovered near Baiji in 2005 were a match.

The FBI did not arrest Alwan immediately. Through the spring of 2011, agents continued to monitor him. They hoped to learn more about his AQI connections and any other IED incidents they could connect to him. By May, though, it appeared that they had learned all they could, so they decided to end the operation. A SWAT team moved in on Alwan and an accomplice during another phoney arms transfer, arresting both.

The story of the AQI bombmaker arrested in suburban Kentucky made headlines for a few days but then was eclipsed by an even bigger news event: the death of Osama bin Laden in a compound in Abbottabad, Pakistan. Alwan's story quickly faded from view.

Quiet though it was, Alwan's arrest was a significant victory. The FBI was able to bring a 23-count indictment against him, including charges of conspiring to kill US nationals abroad, conspiring to use a weapon of mass destruction (explosives) against US nationals abroad, and distributing information on the manufacture of IEDs. Confronted with the evidence gathered by TEDAC, Alwan pleaded guilty. He confessed his AQI affiliation and cooperated with FBI agents in exchange for a reduced sentence. The agency won't disclose the precise information that he divulged as part of his cooperation, but he ended up with a 40-year prison sentence. The accomplice arrested alongside him is in for life.

Perhaps of greater consequence, Alwan's case changed how TEDAC conducts forensics. Techniques pioneered by Suchma's team to quickly analyse the evidence in Alwan's case helped TEDAC analysts rip through a backlog of tens of thousands of unexamined devices. A process many thought would take a decade or more took just five years. Now, no device sits unanalysed for more than 150 days. "Alwan was the watershed moment, that's when we knew we had to get through this as quickly as possible," Carl says. "That's what motivated us to find creative ways to work through it." The quicker TEDAC analysts can process IEDs, the more likely law enforcement agencies in the US and abroad will find bombmakers before they strike again.

Clearing the vestiges of Iraq and Afghanistan from its inventory was symbolic for TEDAC. Today the centre is pivoting from warfighter support in Iraq and Afghanistan to what Carl describes as a "rest-of-the-world" mission. Now, an IED recovered in the Philippines or Turkey will get the same treatment as a bomb discovered in Baiji. Also, acting in partnership

"THEY WANTED TO RUN THIS ONE GUY'S FINGERPRINTS AGAINST EVERYTHING WE HAD. IT WAS A NEEDLE IN A HAYSTACK."

with local law-enforcement agencies, TEDAC has become a global dragnet for bombmakers. For example, in September 2014, Scotland Yard arrested a suspected AQI bombmaker living in northwest London. The intelligence came from TEDAC and an IED recovered in Iraq in 2007.

Moving out of the parking garage at Quantico will no doubt give TEDAC a boost. In Huntsville, the lab will have more talent to draw from; both NASA and the Pentagon maintain major research facilities there.

More important, it will have the room it needs to grow. The more bombs TEDAC analysts collect, the richer the data becomes and the more effectively they will be able to identify terrorists and criminals.

As global conflicts increasingly involve stateless actors drifting across borders from one battlefield to the next, TEDAC provides a form of institutional memory—a way of tying past acts to individuals in the present, no matter where they go. A decade from now, conflicts in places like Libya, Syria, Iraq, Nigeria, Yemen, and the Philippines will hopefully be distant memories. The world might move on, but TEDAC will continue connecting the dots, remembering what everyone else forgot. 📧

Manual

EDITED BY *Sophie Bushwick*

STATS

Time 1 hour **Cost**

\$30

Difficulty

● ● ● ● ●



**FRIGHT
LIGHT**

Build a Flamless Hack-o'-Lantern



It's never a good idea to leave a flame unattended—even on Halloween. But that doesn't mean you have to give up the glow of a "traditional" Jack-o'-lantern. You can create a realistic fire effect by wiring up an electronic blinky

light. This one, inspired by our friends at DIY blog Evil Mad Scientist Laboratories, uses a safe circuit that requires no soldering. It incorporates six LEDs with a candle-flicker effect, which will shine all night on three AAA batteries. And thanks to a phototransistor, which detects light, the LEDs will automatically turn off at dawn and back on at sunset. Trick or treat! **SEAN MICHAEL RAGAN**

200

Estimated residential fires caused by open flames in the US each year around Halloween

**MATERIALS**

- Mini breadboard
- 6 candle-flicker LEDs (2 red and 4 yellow)
- 6 100-ohm resistors
- 2 NPN transistors
- Infrared phototransistor
- 5-kilohm resistor
- Jumper wires
- 3 AAA battery box with switch
- 3 alkaline AAA batteries

TOOLS

Side-cutting pliers



Wire strippers

INSTRUCTIONS

- 1** Assemble the components and jumper wires in the breadboard as shown in the illustration. The LEDs, NPN transistors, and phototransistor (which looks like an LED with a black lens) are "polarised," meaning the circuit won't work as intended if you install them backward. For the four LEDs nearest the switch, place their "flat" sides facing away from the switch; the flat sides of the other LEDs and the phototransistor should face toward it.
- 2** Trim the leads and jumper wires with the pliers as you go so everything sits flush against the breadboard face.
- 3** Peel the film off the adhesive on the back of the breadboard and stick it to the battery box, right below the switch.
- 4** Connect the red battery-box wire to the breadboard corner nearest and left of the switch, and the black wire to the far left corner.
- 5** Load the batteries into the box and turn on the switch. If the LEDs don't come on right away, try covering the phototransistor with your thumb or moving the breadboard into a dark room. The sensor responds to sunlight and bright incandescent bulbs, but not to LEDs or fluorescent lights.
- 6** Set the project inside your carved jack-o'-lantern and place it on an open patio or windowsill. If your carving is fairly open and admits natural light into the pumpkin, the phototransistor should easily detect when the sun sets. But if your pumpkin is dark inside, you might need to leave the lid off to prevent the LEDs from turning on too early in the day.
- 7** Another option is to adjust the circuit's light sensitivity by replacing the 5-kilohm resistor. Swapping it for a stronger resistor (up to 10 kilohms) creates a circuit that turns on only at brighter light levels. A weaker resistor (down to 1 kilohm) makes a circuit that can turn on in dimmer conditions. Woaaaaoooo!

The Roundup

THE
ULTIMATE
DIY SPY KIT

Want to crack an international drug smuggling ring, legitimately be called a gumshoe or just watch birds and other wildlife? Here's the ultimate DIY Spy and Surveillance kit using gear available from Jaycar. From a fun (but effective) spy watch to a serious night vision monocular, there's tech for every covert operation. Just search the provided catalogue numbers on www.jaycar.com.au and get spying today.

LINDSAY HANDMER

1 SPY PEN

Catalogue Number: QC8017

Price: \$89.95

The mainstay of any DIY Spy is a covert camera to snap pictures of documents or secretly hand over to the bad guys to record shady dealings. The pen has 8GB of memory and can record 1600 x 1200 stills, or 720P video at 30FPS. Copying your footage or charging the unit is as simple as plugging it into a USB port. Most importantly, it can also be used as a normal pen to avoid suspicion.

2 PARABOLIC MIC WITH MONOCULAR

Catalogue Number: AM4040

Price: \$79.95

Stakeouts need specialised equipment (not to mention donuts and coffee) and being able to listen and watch your quarry is the top priority. The Jaycar Spy Mic uses a 200mm parabolic reflector to pick up and amplify audio from up to 100m away. Even better it has a built in digital recorder and includes headphones. The unit also has an 8x monocular scope for zoomed-in visual spying and mic targeting.

3 INSPECTION CAMERA

Catalogue Number: QC8712

Price: \$279

In the movies, spies have little micro cameras that can be fed under doors, into safes or through holes drilled in walls. Going the DIY route is actually easy, thanks to a repurposed inspection camera. The unit has a fully waterproof 9mm camera (with LED illumination) on a 1m flexible boom that records at 640 x 480. During a tight squeeze, the screen can even be detached and watched wirelessly.

4 CAMERA DETECTOR

Catalogue Number: QC3506

Price: \$99

Beat other spies at their own game, with a versatile bug detector that helps hunt down hidden cameras and audio transmitters. With a special viewport and pulsing LEDs, it can illuminate a spying camera lens so it can then be disabled. It can also track RF transmissions from 1 MHz all the way up to 6.5 GHz, with an audible tone and visual signal strength meter.



The Roundup**PRIVACY LAWS**

In Australia it's illegal to record audio, video or images of people in areas where there is an expectation of privacy. It is (generally) okay to record in public areas, but different rules can apply state to state. Illegal recording can lead to criminal prosecution and fines, so a good DIY spy will always check the laws first.



7



8



5



6

5 HIDDEN SMOKE DETECTOR CAMERA

Catalogue Number: QC8074
Price: \$199

Wi-Fi enabled IP cameras are an easy way to set up remotely monitored surveillance, but most are not very subtle. So the Jaycar boffins squeezed one into a fake smoke detector. It even has Infrared LEDs so can capture footage at night. The unit has a 1280 x 720 resolution at 30FPS and will stream over Wi-Fi up to 30m. The feed can be viewed and recorded via a web browser, or through a free iTunes or Android app.

6 NIGHT VISION MONOCULAR

Catalogue Number: GG2129
Price: \$319

Illicit activity often hides under the cover of darkness, but with a little technological magic, you can see in the dark. The Night Vision monocular uses an image intensifier tube to boost the available light - check out a video of it in action on the Jaycar website. For use in total darkness, it also has a high powered infrared illuminator. There's a 3x scope, and it can be tripod mounted.

7 CAMERA SPY WATCH

Catalogue Number: QC8070
Price: \$89.95

A fully functional watch, this brand new product also has a tiny HD camera hidden on the face. It can grab snaps at 3264 x 2448 resolution and save them onto the 8GB of onboard memory. You can also record 1280 x 920 video, including audio from a tiny mic hidden in one of the control buttons. Plug in to USB to download the footage and recharge.

8 GPS AND GSM TRACKER

Catalogue Number: LA9011
Price: \$159

Locate and track a vehicle in real time and display it on Google Maps. The unit communicates via a standard mobile sim card and runs for 4 days on its internal battery. It can be set to alert when a vehicle leaves a pre-determined area or exceeds a certain speed. It can also be hardwired into the car, allowing it to remotely disable the engine. Access on the go is simple thanks to Android and iOS apps.

Envable Project

A Laser-Shotgun. Really.

There's no real reason a 40-watt laser shotgun should exist. But building one isn't illegal, just challenging. So this past June, Drake Anthony, then a college junior, gave it a go.

Rather than make a laser gun with a single powerful beam, Anthony decided to combine eight parallel 5-watt lasers. A lens would focus the beams to produce a concentrated blast of photons—similar to how a shotgun's choke controls the spread of pellets. During a break from his busy schedule at Southern Illinois University, the chemistry-maths-physics triple major worked for two days, stripping wires, soldering parts, and troubleshooting bugs. The effort paid off. His 40-watt shotgun can set paper on fire, melt Ping-Pong balls, and burn wood.

"It's very, very strong and extremely dangerous," Anthony says. "But once I realised it was possible to make it, I had to try."



Anthony—better known to his 170,000 YouTube followers as styropro—has been hacking lasers since he was 12 years old. Now 23, he has built and documented more than 100 homemade lasers and laser devices, such as lightsabers and lava lamps. The videos of his exploits helped him score a job in a physical chemistry lab at his university,

WARNING: Anthony's laser projects can be very dangerous. So don't try this at home—you'll scorch your eyeballs out.

where he uses lasers to make MRI instruments more sensitive.

Now that he's a senior, Anthony is debating what to do for his life's work. He only knows he wants it to be equally crazy. "Ridiculous, high energy—just crazy!" he says. "So there's a good chance that lasers might be involved." **RACHEL NUWER**

Toolbox

FLEX YOUR MAKER MUSCLES

In 2006, undergraduate Brian Kaminski was building his senior design project: a glove to help stroke victims regain hand function. He needed a sensor to detect the electrical impulses sent to muscles, but he couldn't find one for less than \$1,000. Kaminski dropped the glove project, but the idea of a cheap muscle sensor stuck with him. Five years later, he created one. "I decided to hand-solder a few circuit boards and put them up for sale, thinking I would get only a few orders a month," Kaminski says. He was soon scrambling to keep up with demand.

To use "bionic claws," snap electrodes to the MyoWare sensor, and stick them on your arm. Then flex and—SNIKT!

The current version of Kaminski's device, called MyoWare, reads the electric potential in a muscle through electrodes stuck to the skin. Based on how hard the muscle is flexing, the sensor increases the signal sent to a micro-controller chip, which can trigger an action. To demonstrate, Kaminski built Wolverine claws that shoot out when he flexes his arms. MyoWare is available through the website for his company, Advancer Technologies. **DAVE GERSHGORN**



Biotech Opens Up

GENE
REMIXER



In 1999, 19-year-old Sean Ward created one of the first music-recommendation algorithms, dropped out of the University of Virginia, and started his own company. By age 25, he had tired of the conflict between record companies and Internet users, so he turned to something completely different: bioengineering.

"In many respects, genetic engineering is the ultimate remix technology," Ward says. Bioengineers copy DNA from one organism and adapt it for another to create life-forms that change colour, glow, or produce new medicine or materials. In today's high-speed, high-volume biolabs, automated tools like pipetting robots do most of the work—and each requires different kinds of code. Ward saw that, like music, biotech research had become digital. And also as with music, he could use his programming skills to give more people access to it.

This past November, Ward's company, Synthace, released Antha, the first open-source programming language that works across different biotech machines. Anyone who can code can write commands in Antha to direct all of a lab's equipment. This allows researchers—or programmers with a yen for genetic engineering—to more easily perform complex experiments, and share how they did it.

Ward was one of the first to see the potential of DIY genetic engineering, but he's not the last. Other companies are now producing tools that make it possible for amateurs to create new organisms—or, in Ward's words, to "program the assembly of matter."

DANIEL GRUSHKIN

Three Tools for DIY DNA

ON THE COMPUTER

Arcturus BioCloud allows beginners to design basic bioengineering experiments through an online interface. The service sends the directions to a pipetting robot at a remote lab and then displays the results.

\$80 and up

IN THE KITCHEN

Using kits from Synbiota, home hobbyists can start engineering color-generating *E. coli* with little more than pipettes, tubes, and the kitchen sink.

\$395 and up

AT THE HACKERSPACE

OpenTrons produces a pipetting robot 10 times cheaper than conventional machines.

Biohackers can download instructions for an experiment, calibrate the robot, and then simply hit "run."

\$3,000 and up

8,800

Number of times per minute
the bristles of an electric
tooth brush can oscillate

USE AN ELECTRIC TOOTHBRUSH TO...

GOOD IDEA

SAND THE SMALL STUFF

Last June, professional DIYer Kip Kedersha turned an electric toothbrush into a \$5 mini power sander. Kedersha, who posts how-to videos on his YouTube channel, Kipkay, first cut the bristles off an Oral-B electric toothbrush. Then he hot-glued a small plastic circle to the head and attached self-adhesive sandpaper. The sander can make small cuts or grind fine details on plastic models or miniatures. "It fits the bill for a hobbyist," Kedersha says, "and it's a deal."

BAD IDEA

GIVE A TATTOO

Daring inkers have discovered that an electric toothbrush can also drive the needle of a DIY tattoo machine. But it's hard to control the needle's depth, which increases the risk of serious infections and scars. "There's nothing good about getting a toothbrush-machine tattoo, nothing whatsoever," says professional tattoo artist Gerald Feliciano. "You can buy almost any rinky-dink machine that will work better than that." **LEVI SHARPE**



ILLUSTRATION BY CHRIS PHILPOT

Bookmark



FOUNDRY

When Foundry launched in March, Ryan Craven used the project-sharing website to show off the hoverboard he'd built in 2014. Rather than asking for step-by-step instructions, like other DIY sites, Foundry prompted Craven to describe his inspiration (*Back to the Future Part II*) and the challenges he faced ("Many long bike rides to and from Home Depot in the hot Texas sun").

"Foundry is for people who want to sit down and learn the stories behind the creations," says founder and CEO David Endler. Eventually, Endler hopes the site will create a connected community of entrepreneurs, becoming a professional network for the maker movement.

REBECCA HARRINGTON

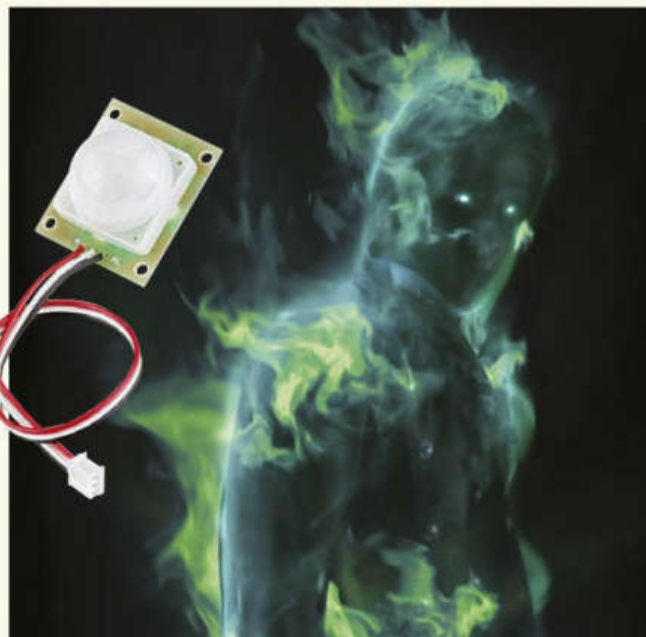
Passive Infrared



Last Halloween, radiologist George Poulos decided to make his yard extra scary. His plan: Every time a pedestrian passed by, a projector would shine a ghostly animation on a plexiglass pane to make it look like a real ghoul had appeared. It was too dark to rely on a traditional motion sensor, so Poulos used a \$10 passive infrared (PIR) one. Every object warmer than absolute zero emits infrared rays, and as one source of radiation passes in front of another, a PIR sensor detects the difference. DIYers can use PIR sensors day or night to automate security cameras, open doors for pets, help trigger Nerf sentry guns — and terrify trick-or-treaters. **R.H.**

'pa-siv in-frə-'red

n. A method of detecting motion by observing the slight difference in radiation when one object passes in front of another

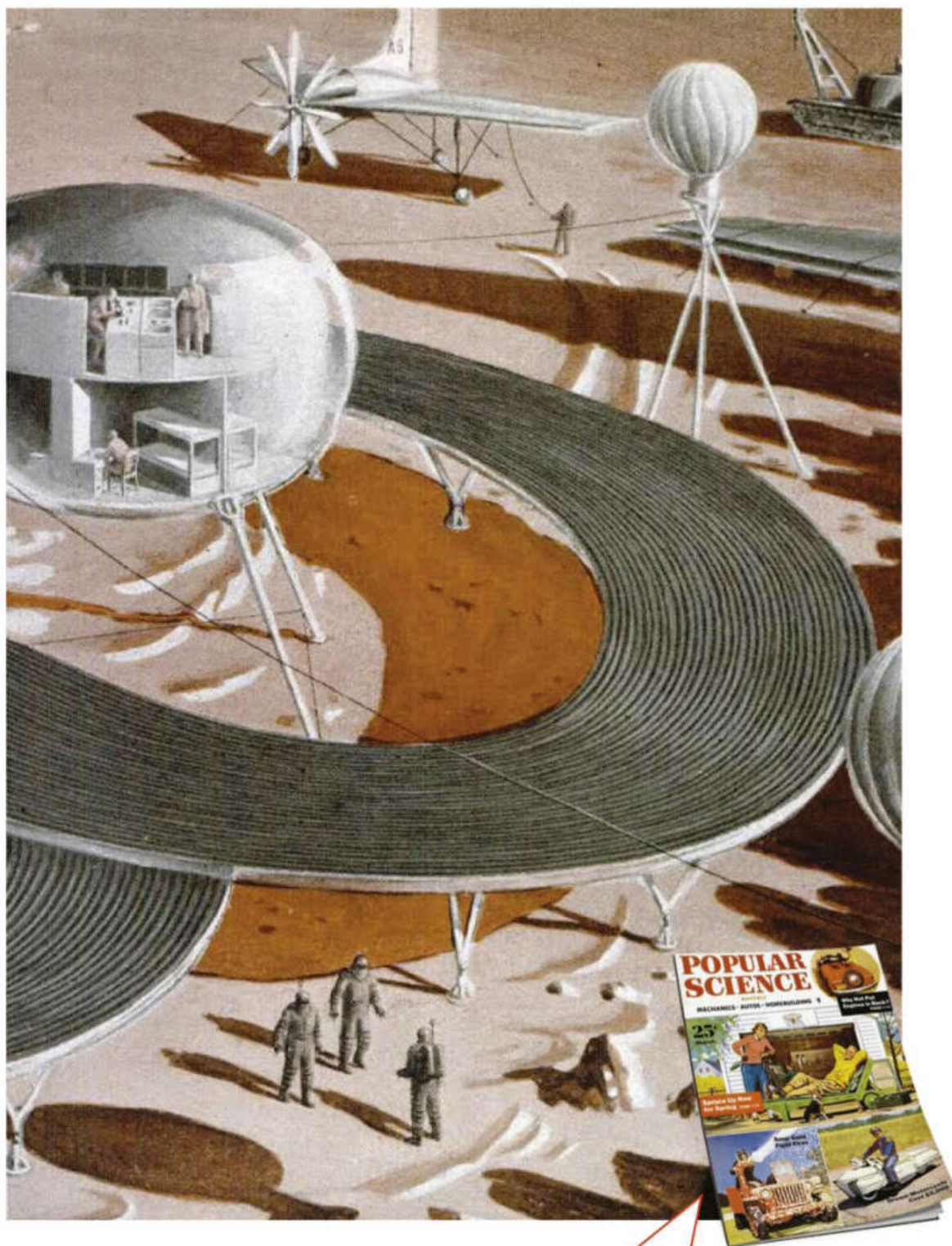


FROM LEFT: COURTESY RYAN CRAVEN; COURTESY SPARKFUN.COM; COURTESY ATMOS FX

A RED PLANET TO CALL HOME

In 1953, people had yet to see a close-up image of Mars. But that didn't dim the prospect of one day living there. In March of that year, *Popular Science* featured a plan—developed by a graduate student with the input of government scientists—outlining how 33 Earthlings might one day live on the Red Planet. Their spaceship would serve as the base's hub. A heart-shaped ring of solar panels would warm the living quarters, and wind generators would provide power. And alien invaders? There was a plan for them too. Decontaminating mist would kill any Martian germs clinging to the crew's space suits as they entered the base. Today, life on Mars is still the subject of avid speculation. The producers of *The Martian*, a film to be released in theaters October 2, also consulted government scientists to bring their vision to the big screen. For more from director Ridley Scott, turn to page 54.

REBECCA HARRINGTON

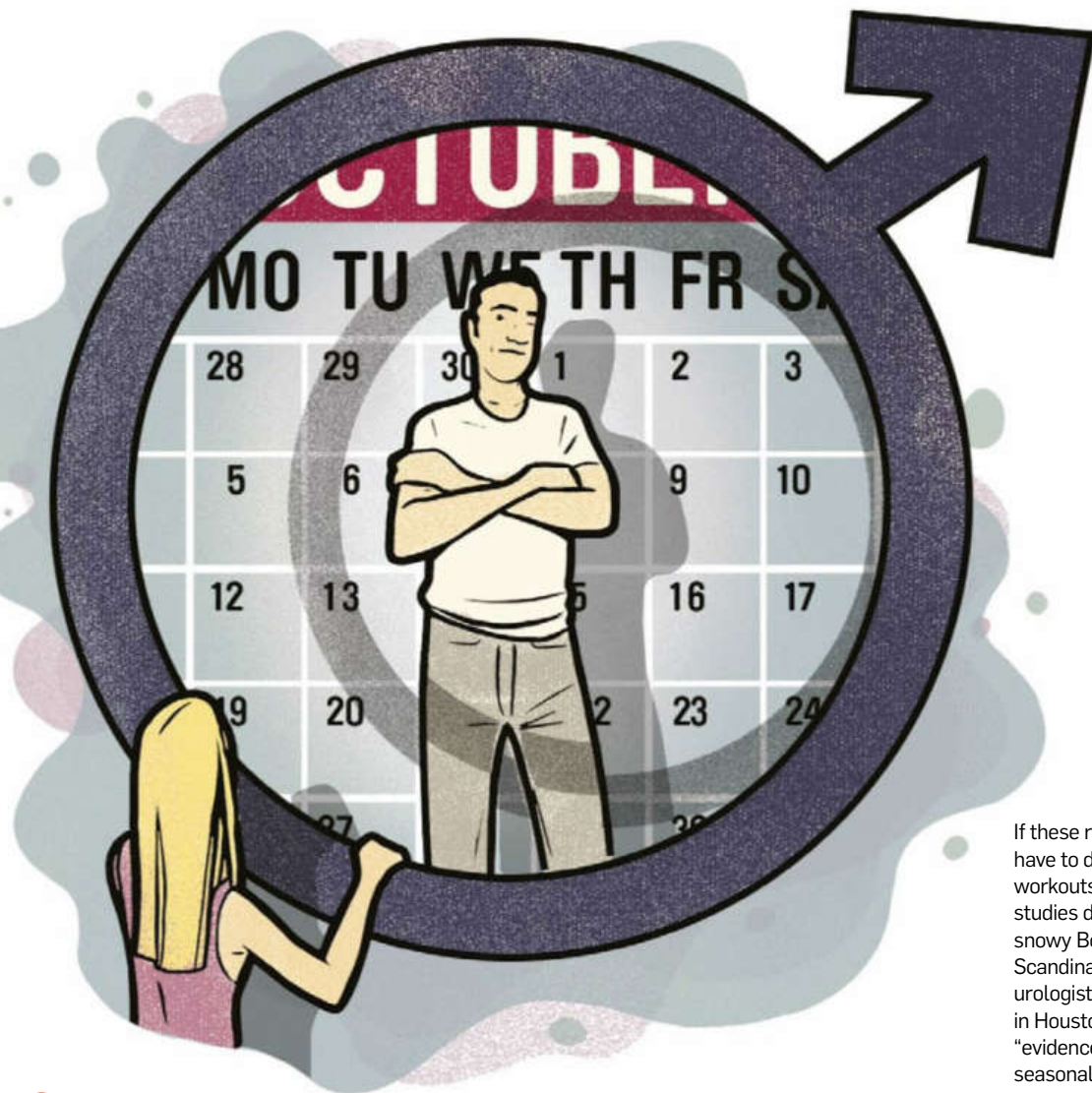


“And so the initial landing on Mars must necessarily be an adventure fraught with the utmost peril. But if history repeats itself, there will be no dearth of volunteers, prepared to gamble their lives to advance the frontier of human knowledge.” — *POPULAR SCIENCE*, MARCH 1953

Go Ahead . . .

Ask Us Anything

ANSWERS BY **Daniel Engber**
ILLUSTRATIONS BY **Jason Schneider**



Q: Do men have hormonal cycles?

Short answer Ever heard of man-struation?

A:

Men do go through hormonal cycles. That much is established. Their testosterone levels tend to peak first thing in the morning, perhaps in concert with circadian rhythms, and then diminish over the course of the day—though exercise can cause fleeting spikes. What science has yet to show is whether hormones dip and rise over weeks or months, as women's do.

Some researchers believe that male hormones vary with the seasons. A 2003 study found that the testosterone levels of men in one Norwegian town bottomed out in summer and reached a high in autumn. A study of Danish men found similar seasonal variations (on a slightly different schedule).

If these rhythms are real, they might have to do with sun exposure, summer workouts, or winter weight-gain. But studies done in sunny San Diego and snowy Boston failed to replicate the Scandinavian findings. In a 2012 review, urologists at Baylor College of Medicine in Houston concluded that some "evidence exists to support the notion" of seasonal cycles but cautioned that more research was needed.

Endocrinologist Peter Celec of Comenius University in Slovakia, thinks that men have a straight-up monthly hormonal cycle too. In 2002 he published a study showing that both men and women experience roughly lunar rhythms of testosterone; the levels in men's saliva peaked dramatically on day 18 of a 30-day cycle. Celec's findings have not been replicated or accepted in the field, yet he remains convinced: "I have searched the literature for negative findings, but I have not found anything."

Celec adds that if women didn't bleed, the research establishment would likely be skeptical of their monthly cycles too.

Have a burning question?
Email it to letters@popsci.com.au



Q: DOES COFFEE GIVE YOU A DIFFERENT BUZZ THAN TEA?

Short answer
Yes, in subtle ways

A:

Eighty-nine per cent of adults regularly consume caffeine, according to the Centres for Disease Control and Prevention. Two-thirds get it from coffee, one-sixth from tea, and the rest from soft drinks. People tend to assume caffeine is the only stimulant in these beverages, but tea, and even hot cocoa, contain other compounds thought to have psychoactive effects. And their levels of stimulation vary.

Caffeine is still the most intense stimulant. "It blows the others out of the water," says Crystal Haskell-Ramsay, a nutritional psychologist at Northumbria University in England. But caffeine doesn't act alone.

Tea, for example, contains the amino acid theanine. In 2008, Haskell-Ramsay showed that subjects who took large doses of caffeine and theanine together felt more alert than if they had taken them separately. The subjects also had better reaction time and working memory. A follow-up using smaller doses, comparable to the amount in a cup of tea, found the opposite: Theanine killed the caffeine buzz. "I think it's dose-specific," Haskell-Ramsay says.

Still, not everyone feels the same energy jolt from a given beverage. "There are genetic differences in how people respond," Haskell-Ramsay says. She, for one, avoids coffee. "It's too stimulatory for me," she says. That is, unless she's desperate. "I was at a conference once, and the tea was terrible. By day four or five, I was so caffeine-deprived, I finally bit the bullet and ordered a cappuccino."

Q: WHAT'S WITH ALL THE MOVIE MATHEMATICIANS?


Short answer A solitary genius makes for a better screenplay

A:

This year's Academy Award nominees for Best Picture included the life stories of not one but two scientists: astrophysicist Stephen Hawking (*The Theory of Everything*), and computer scientist Alan Turing (*The Imitation Game*). The fact that both men have made their breakthroughs in quantitative fields isn't serendipity. Math nerds in movies seem to be multiplying.

"We're fascinated by computability," says T. Hugh Crawford of Georgia Tech, who has written about science depictions in cinema. Figures such as Hawking and Turing can serve as heroes of the digital age. More important, they're the sort of scientists who work alone, and Hollywood loves a lone wolf, Crawford says.

The affinity for a solitary hero isn't new, but the fact that this hero can be a physicist certainly seems to be. Film scholar George Frederick Custen found that only six per cent of the 291 biopics released between 1927 and 1960 were science-themed; almost half of those told the stories of clinicians—nurses, doctors, even a dentist. Most of the rest depicted inventors, such as Alexander Graham Bell and Thomas Edison, or lab researchers like Louis Pasteur and Marie Curie.

Early science biopics portrayed the nitty-gritty reality of working as a chemist or bacteriologist. "Ninety per cent of the Marie Curie film is just showing the rote difficulty of doing lab practice," Crawford says. Recent biopics have taken a different approach, choosing instead to feature mathematicians or theoretical physicists, whose work can be imagined (and even misrepresented) as a series of Eureka moments. But one thing these scientists all have in common: love interests. Ah, Hollywood. 





SONY BETAMAX

Pressing play/record on home videotape history



Think the last round of format wars like HD-DVD vs Blu-Ray were tough? Nothing beats Betamax vs VHS. The early video recorder market was actually dominated by Sony (along with other manufacturers at the time who jumped on board), with the U-matic - a cassette style recording system. The problem was it was crazy expensive and was never very popular in the consumer market, but did pretty

Betamax had a more compact tape than VHS, but losing the race to two hour run times cost Sony the format war.



well in the professional segment.

Philips released the first real consumer machine, with the N1500 VCR, while other brands tried their luck with a variety of different products.

It wasn't all video on tape either - Philips embraced lasers and rolled out the technically superior but not very successful LaserDisc. Other formats included Capacitance Electronic Disk, a kind of analogue video record that played back with a physical needle.

THE FORMAT WARS

In the early 1970s, Sony put the word out for other companies to collaborate on a new format to really take over the consumer market. Matsushita and JVC (who had also been a part of U-matic) were keen, but had an issue with the tape's 60 minute recording length. That's long enough for your soaps, but not long enough for a whole movie.

Sony didn't really think it was much of a problem and despite the partner brands' hesitation, launched Betamax in 1975. And that is when things went awry. Once Sony was fully committed to its 60 minute

Betamax release, JVC started the war by releasing VHS, which could record for two hours.

Sony pushed on with Betamax and eventually upgraded to a two hour recording length, but it was too late. Thanks to a cheaper price, VHS had managed to make some serious sales and was looking like it would put Betamax out of business.

It was especially popular with an emergent market Sony obviously hadn't predicted: rental of movies on video, as an entire movie could fit on a single tape.

But the fight wasn't yet over, as Sony scrambled to get some big name partners (such as Zenith) and pushed for market share in the USA.

A VICTOR IS CROWNED

Rumour has it that the porn industry's support for VHS was the deciding factor, but in reality it was something that Americans possibly love even more: sport. Or, as they put it, "sports".

Network heavyweight (at the time) Radio Corporation Of America (RCA) was still sitting on the fence about which format to support. After all,



Betamax machines were quality, offering more features than many VHS units. But they were also more expensive.

refused to die for a **long time**, and lived on in many ways.

BETACAM

While Sony got outdone by VHS, Betamax went on to create a very long lasting professional recording system. Introduced in 1982, Betacam replaced the earlier U-matic system that Sony had released over 10 years earlier.

The key to Betacam was broadcast quality recording (and the ability to edit frame-by-frame) - the first tapes could handle 300 lines of horizontal resolution. The actual tapes were the same as Betamax, but used extra recording heads and a much faster (10.15cm vs 1.87cm) tape speed. This let Betacam record much higher quality at the expense of tape length, with only 30 minutes compared to regular Betamax's (at the time) 3 hours.

VHS tried to compete with a professional standard, called M-Format, but it made little headway against the entrenched use of Betacam.

BETAMAX VS VHS QUALITY

The claim always is that Betamax has better quality, but that doesn't tell the whole story. Certainly, the 60-minute Betamax tapes offered higher quality, with 250 vertical lines vs 240 for VHS, as well as lower video noise. But later Betamax tapes had to compromise and drop down to 240 lines to fit in 2 hours of footage. Image quality between the formats was very similar at that point, and depended a lot more on other factors such as the TV than it did on the tapes.

WHAT IS IN A NAME?

VHS is pretty straightforward - Video Home System. Betamax is a little less obvious. According to Sony, beta has a double meaning - firstly it's the Japanese name for how the signals are recorded. Secondly, as the tape runs through the recording and reading heads, of the machine, it takes the form of the Greek letter beta (β). And max? Well that was just slapped on the end to suggest greatness. In Today we have "Blu-ray" to describe high resolution optical disc storage. One of the inventors, and thus winners of the HD format wars? Sony.

In 1986, Betamax SP (superior performance) was launched, which offered even better quality and up to 90 minutes of recording time.

In 1993 Digital Betacam made its debut, recording PAL (720 x 576) or NTSC (720 x 486) with a 90 Mb/s bitrate and run times up to 124 minutes. Three years later, the cheaper Betacam SX brought MPEG compression and managed even longer recording times.

Despite not offering HD resolutions, Betacam is still in use for professional recording today, especially large cameras used for in the field broadcasts. 📺

two hours still wasn't enough to record a full game of American football, so they announced they would support the format that could deliver a 180 minute tape.

Matsushita (using a new brand called Panasonic) jumped on that offer with VHS and promised a mighty 240 minutes - four hours. And they delivered too, selling a million units over the next three years and effectively putting Betamax out of business. Of course, the format



MISADVENTURES IN AUTOTROPHY

↓
As I lay on the floor in my apartment, ethnic cornflour coating nearly every surface, too weak to even lift my head, I reflected that my attempts to save money had once again backfired.

"Aristides!" I called for my cat, weakly. He was long gone. Various indignities involving a leash and my recent radical change in diet - his and mine both - had combined to convince him that life would be better somewhere else. Anywhere else.

An alarm sounded on my smartphone. It was on the other side of the room and I wasn't sure whether I had the strength to crawl over there and swipe it off. The alarm meant I was supposed to mix up another batch of DIY total nutritional replacement powder, blend it with water, and drink it down. From my current position, it seemed an impossible task.

As usual it was all the internet's fault. I'd been looking for scientific tests to be part of, down at the local library, and happened upon a blog post explaining Soylent. Apparently, some Silicon Valley wunderkind invented a powder that totally replaces food. For him it was all about convenience and hipster cachet, but for me it was all about the promised \$3.50 per day cost of staying alive.

Even after I found out it was US\$3.50 (\$4.95) I was still on board, because the tendons in my wrists were beginning to resemble the two-minute noodles

I usually subsisted on during these occasional but crippling periods of low scientific test activity.

"Why won't someone probe me!" I wailed from the floor in my apartment, three weeks later. Three weeks after I'd bought a whole bunch of vitamin supplements and masa harina in bulk. Three weeks after I'd started on an exclusive diet of vaguely Tortilla-flavoured milkshakes.

For the first week or so everything was great. Sure, I was hungry all the time and the sugar withdrawal was pretty debilitating, but I quickly realised I'd save dollars a month on toilet paper. As the second week drew to a close I started falling down quite a lot, but didn't really let this bother me as I was spending most of my time slumped on the sofa wondering what it would be like to be able to afford an internet account so I could get Netflix and then spend all my time watching Netflix but of course that would require affording a Netflix account too and... it was about this time that I realised I was drooling.

Two days later my spit dried up and I had my first seizure. Choking down another tortilla milkshake, I considered hitting the streets to try and find a doctor who still bulk-billed. But did I have the energy to fill out the new patient form, what with all the exotic diseases I'd be obliged to list? Probably not.

Colour leached from the world as I sat on the couch. My left leg started dancing around on its own accord so I decided I might be more comfortable lying on the floor. Which

is where we came in.

Dust mites rose from the ancient carpet and tried to activate my allergies, but my entire histamine system seemed to have shut down. Even my tonsils were dry - this was a new and exciting sensation.

"Urgh," I managed. I called out for Aristides again, and imagined I saw wild leaping cat-shadows on the wall, but there was only silence. Silence and the all-pervading smell of masa harina.

Someone knocked on the door. I smiled and mimed opening it from my position on the floor in front of the couch. Someone knocked again. Then someone kicked in the door. It was a distinctly feminine kick.

"Oh God," said Atalanta, my colleague-in-test-subjectdom and sort of but not really on-again-off-again girlfriend. "What stupid pills have they got you on this time?"

She stood over me. My chemically imbalanced brain tried to make sense of her features, but all I could see were eyes. Like Google's quantic dream in real life and twice as scary.

"No pills," I rasped. "Just powder. Nutrition. Food is... food is obsolete. Future of modern living. Simple powder, mixed it myself. May have... left out a few essential trace... masa harina... so much corn..."

Darkness swam in from the edges of the world and I slipped mercifully into a coma. Ironically, while I was intubated at taxpayers' expense in a city hospital, they used a properly formulated professional medical version of that food powder to keep me alive. It took six weeks for my liver to reboot.

The moral of this story? Soylent green may have been people, but DIY food powders are just cornflour and hipster pretension. And man cannot live by those alone. 🐁



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